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ORIGINAL ARTICLES.

A Contribution to the Geology of the Country between Petermann Peak and Kjerulf Fjord, East Greenland.

By J. M. Wordie and W. F. Whittard.

(PLATES VIII–X.)

I. Introduction.

THE Cambridge Expedition to East Greenland in 1929 set sail from Aberdeen on 2nd July in the sealing-sloop *Heimland*, which had been chartered from Tromsö, Norway. Taking the Fair Isle passage, the edge of the pack-ice was reached six days later, and entered in the region of latitude 71° 30′ N., longitude 15° 30′ W. Last summer proved unusually difficult for navigation in the East Greenland ice-current, and it was not until 4th August after a month in the ice that we reached land-water and anchored in Mackenzie Bay. From the Bay a course was steered westwards along Franz Josef Fjord to the foot of the Riddar Valley on the west side of Kjerulf Fjord. Here the party divided; the ship-party with two geologists during the next fortnight studied the tectonics shown in the great cliff-sections bounding Franz Josef Fjord and King Oscar Fjord (Davy Sound) and their branches (Fig. 1),[1] while a second party of six was landed near Riddar Valley in order to map the tract of country lying immediately to the west of the head of Franz Josef Fjord (Fig. 2). Their ultimate objective was Petermann Peak, discovered by Payer and Copeland of the German Arctic Expedition of 1869–70, and estimated to be 11,000 feet high.[2] A hurried reconnaissance in 1926 to the Cambridge Peaks had shown that the most likely route to the interior would be westwards along the watershed between the head of

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[1] The geological results obtained in the fjords form the subject of another paper which is not yet completed.

[2] Koldewey, K. *Die Zweite Deutsche Nordpolarfahrt in den Jahren 1869 und 1870*, vol. i, p. 674. Leipzig, 1874. Last summer the height was found to be 9,650 feet.

Kjerulf Fjord and the Nordenskiöld Glacier.[1] The land-party left Kjerulf Fjord on 6th August, reached Petermann Peak on 15th August, and returned to base on 18th August. The present paper embodies the geological work carried out during the mountain journey, and is based on collections made by Mr. J. M. Wordie and Mr. V. E. Fuchs.

II. THE GENERAL GEOLOGY OF THE COUNTRY BOUNDING FRANZ JOSEF FJORD.

Commencing at the foot of the Nordenskiöld Glacier, Franz Josef Fjord extends in an easterly direction for a distance of 110 miles. The fjord is bounded by rock-walls which may attain a height of 6,000 feet, while there are many cliffs falling almost sheer for 3,000 feet. The wide range of colour of the strata, the almost complete absence of chemical weathering, the bareness of the rock-walls, and the large scale of the country as a whole permit a determination of the general tectonics even from the deck of a ship ; the conditions, therefore, are particularly favourable for a geological study of a fjord-region which is navigable for six weeks only in a normal year.

In general, the youngest beds occur at the sea-coast while progressively older sediments are found to the west, the lowest member being certain metamorphic rocks, considered to be of pre-Cambrian age (see Fig. 1).[2]

The youngest rocks represented in the region are a series of volcanic and intrusive rocks, which belong to the TERTIARY volcanic episode. On Sabine Island and elsewhere they contain interbedded plant-bearing sediments yielding a flora which is relegated by Professor F. J. Mathiesen to the Palaeocene or Eocene.[3]

In the district of Cape Franklin and extending north into the Giesecke Mountains, the Tertiary lavas rest upon a belt of granites believed by Dr. Koch to be intimately related to earth-movements of Caledonian age.[4] West of Cape Franklin and Cape Humboldt, however, the Tertiary lavas are underlain by gently folded sediments of the OLD RED SANDSTONE from which Nathorst collected *Holoptychius* and *Asterolepis*.[5]

The Old Red Sandstone, consisting of sandstones and conglomerates, rests with pronounced unconformity upon the FRANZ JOSEF BEDS [6] which include limestones, quartzites, grits,

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[1] *Geographical Journal*, September, 1927, p. 233.

[2] The term pre-Cambrian is here used for all rocks older than the Cambrian, whether they are sedimentary, igneous, or metamorphic.

[3] "The Geology of East Greenland," *Medd. om Grønland*, vol. lxxiii, p. 202, 1929.

[4] Ibid., p. 64.

[5] *Bih. till. K. Sv. Vet. Akad. Handl.*, vol. xxvi, no. 10, 1900.

[6] *Geographical Journal*, September, 1927, p. 252.

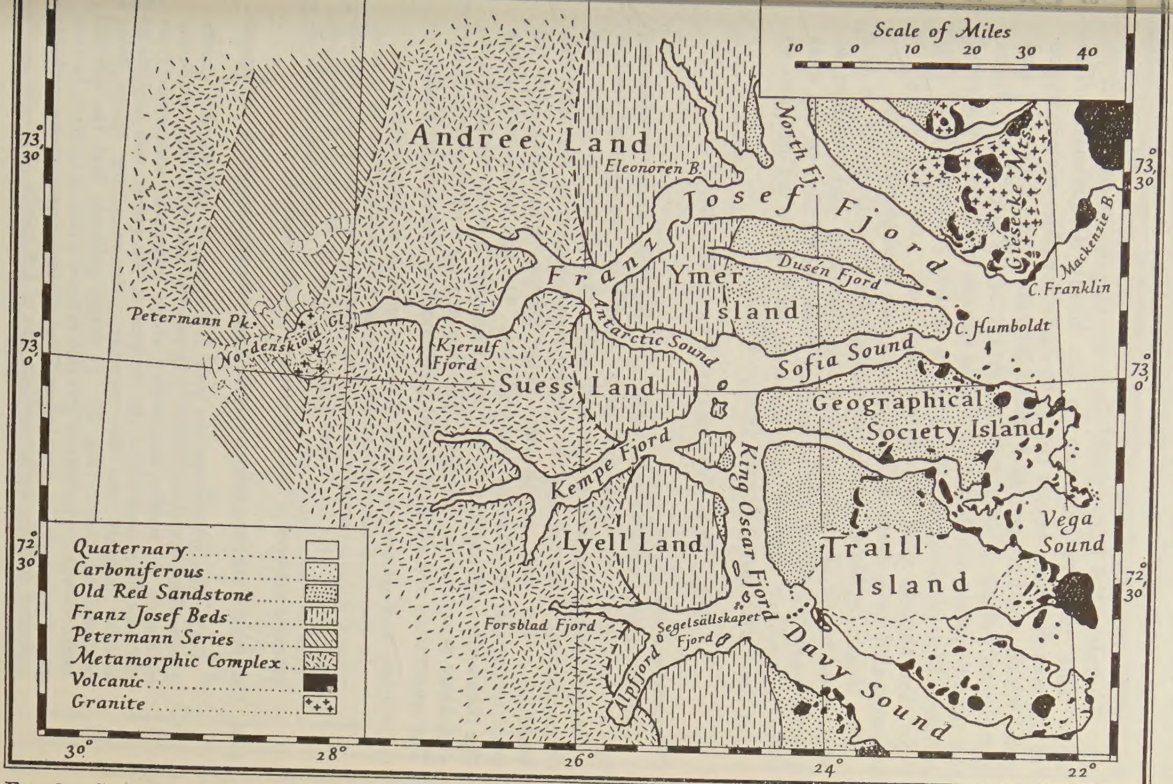

FIG. 1.—General geological map of the country between Franz Josef Fjord and Alp Fjord, East Greenland. [Outcrops of **rocks younger than the Old Red Sandstone have been taken from maps by Nathorst, Nordenskjöld, and Lauge Koch.]**

and slaty rocks. Dr. Koch has obtained fossils from these beds and has proved the presence of Lower Cambrian, Ozarkian, and Ordovician horizons. He has also separated the lowest horizon as the ELEONOREN BAY FORMATION and described it as of pre-Cambrian age. Therefore the Franz Josef Beds are at present considered to range from the pre-Cambrian to the Middle Ordovician. The Franz Josef Beds are thrust from the east over older metamorphic rocks which are here grouped as the METAMORPHIC COMPLEX, and thought to belong to the pre-Cambrian. In Franz Josef Fjord this thrust-system consists of two main thrusts separated by several hundred feet of sheared rocks; when traced southwards to Alp Fjord the thrusts pass into a reversed fault, and this change is accompanied by a decrease in the thickness of sheared rocks.

The Metamorphic Complex was supposed to extend far to the west underneath the ice-cap, but the discovery last summer of quartzites in the region of Petermann Peak shows that to the west there is another outcrop of sediments, and these we propose to name the PETERMANN SERIES (see p. 151).

III. THE PETERMANN PEAK REGION.

Petermann Peak.

The upper part of the Peak consists of platy quartzites weathering to a dark-grey or buff colour; they are succeeded below by red-weathering grey-green and pink quartzites, of which the characteristic features are the strong ripple-marking and current-bedding. On the south-east ridge these quartzites are in turn underlain by black papery shales. On the south-west ridge the rocks dip approximately 30° in a west-north-westerly direction, and they traverse undisturbed the eastern face of the mountain. The quartzites are at least 3,500 feet thick on Petermann Peak.

(91)[1] Platy buff-coloured quartzite from the summit of Petermann Peak.
In thin slice the rock is seen to consist of clastic grains of quartz, around which secondary siliceous material has been deposited in optical continuity; this has resulted in the filling-up of many of the interstices of the original grit or sandstone. In many cases the intergranular material is an indeterminate sericitic matter.

(92) Brownish-weathering black quartzite from near the summit of Petermann Peak.
Under the microscope the rock is formed of well-rounded quartz grains which are often fringed with sericitic material. The cementing substance is mainly magnetite, which originates sometimes from the sericitic veneer round the margins of the grains, and projects as acicular crystals into the interstices, the remaining spaces being occupied by quartz (Fig. 3). It seems probable that the original sediment was a quartzite or grit rich in ferric oxide or hydrate, but the preservation of the rounded outlines of the quartz grains probably indicates that the metamorphism was of low grade.

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[1] Collection numbers of the specimens housed in the Sedgwick Museum, Cambridge.

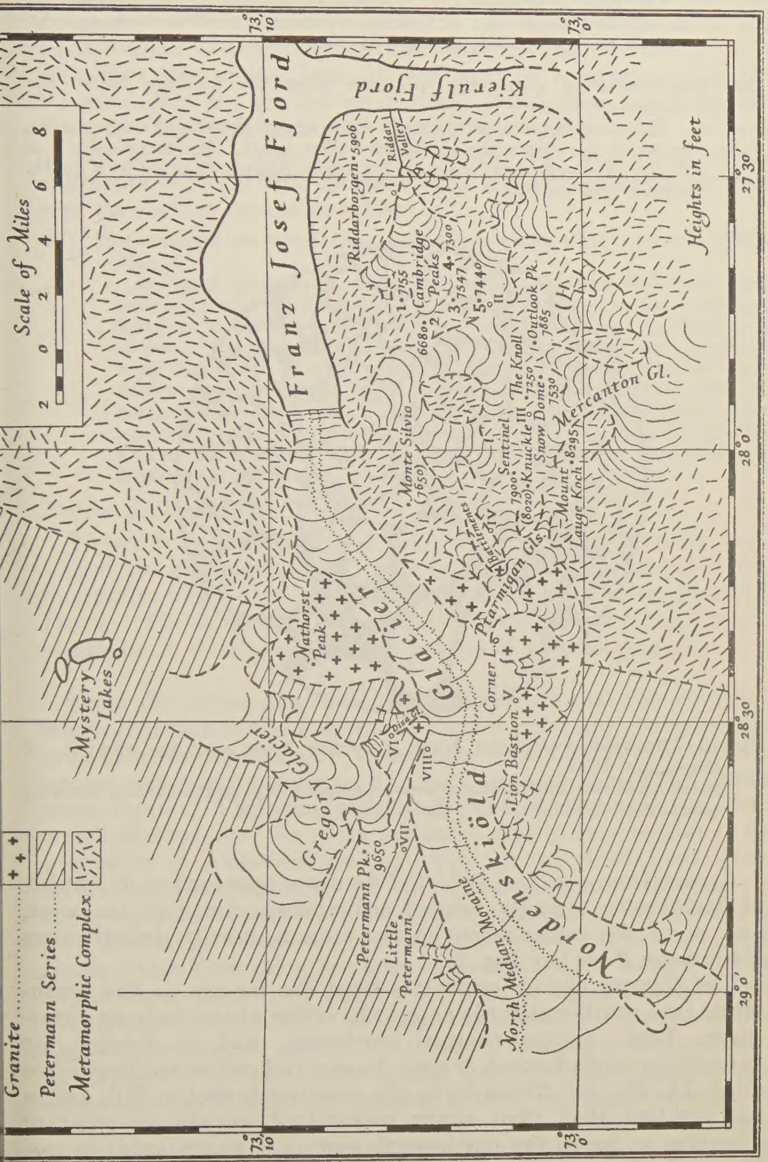

FIG. 2.—Geological map of the country between Kjerulf Fjord and Petermann Peak, showing the outcrop of granite lying along the junction of the Petermann Series on the west and the Metamorphic Complex on the east. I–VIII: camp-sites; 1–5: the five Cambridge Peaks. Heights of the mountains are given in feet, and glaciers are shaded. Only the median moraines of the Nordenskiöld Glacier are indicated.

(93) Massive pink quartzite from the south-west ridge between 8,200 and 8,900 feet.

The rock is composed of rounded quartz grains held together by an interlocking mosaic of quartz. Accessory minerals such as tourmaline and zircon are moderately abundant.

(94) Red-weathering grey-green quartzite from the moraine below the south-west ridge.

The rock is a coherent quartzite showing well-developed ripple-marks, in which the crests are about 0·8 inches apart. Microscopically it is fine-grained and shows irregular masses of quartz cemented by a quartz mosaic and sericite.

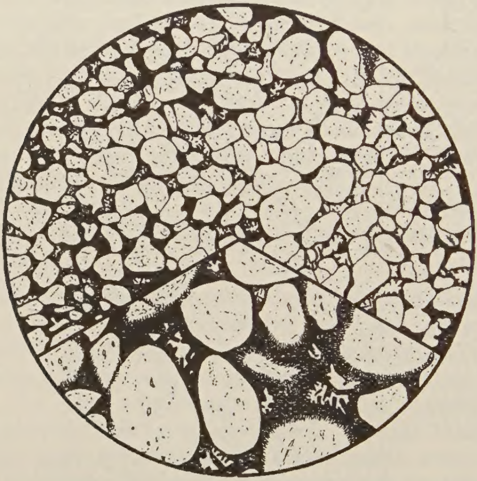

Fig. 3.—Brownish-weathering black quartzite from near the summit of Petermann Peak.

Black areas and line shading represent, respectively, magnetite and sericite; quartz is left white. × 11; the enlarged area × 33.

As seen from a distance, *Little Petermann* appeared to be formed of dark-brown strongly banded sediments inclined to the west, and to be the continuation of the section already described on Petermann Peak (see Fig. 2).

The *Gregory Glacier* originates from the ice-cap to the north-west, cuts south-eastwards across the strike of the beds on Petermann Peak, swings sharply north-east, and is flanked by magnificent cliffs formed of grey, brown and yellow sediments (see Plate IX, Fig. 1). These dip to the west-north-west at 30°, and it was evident that their strike maintained an almost constant direction as far to the north-north-east as it was possible to see. The unbroken sequence, the massive bedding-planes, and the multicoloration of the rocks formed most distinctive features.

Disa Glacier.

The eastern junction between the Petermann Series and the Metamorphic Complex is obscured in the region of the Disa and Nordenskiöld Glaciers by an intrusion of granite (see p. 152). On either side of the Disa Glacier, near its confluence with the Nordenskiöld, the greyish-weathering granite has tilted up and disturbed the blue and grey banded quartzites which are now in the form of a syncline. The granite has also invaded the sediments as veins and stringers, and has altered some of them near its contact into mica schists.

(95) Biotite-muscovite schist, from ridge above Camp VIII, west side of Disa Glacier.

In hand specimen a dark, fine-grained, banded rock with small muscovite and biotite flakes. Under the microscope, the banding is found to be due to a richness in magnetite accompanied by idiomorphic zircons. The magnetite occurs in two habits; as clusters associated with biotite, or as dust which is more or less restricted to bands. Biotite and muscovite occur in about equal quantities, and the muscovite together with quartz constitutes the groundmass. Small apatite crystals are scattered through the rock. A test for graphite proved its absence. The original rock seems to have been an argillaceous sediment.

Nordenskiöld Glacier.

Viewed from Camps VI and VIII, the Lion Bastion on the south side of the glacier appeared to be composed of brown-weathering quartzites, which abut against granite near Camp V (see Plate IX, Fig. 2). The steep cliffs immediately above the latter camp consist of granite in which are included masses of bedded quartzite.

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From the above descriptions it is apparent that the sediments which crop out in the Petermann Peak district are quartzites and grits with associated shales. These rocks are not continuous with any known sedimentary outcrop, and they are here named the PETERMANN SERIES. They are probably of pre-Cambrian age; no fossils were collected, and the rocks are lithologically very similar to the quartzites of presumed pre-Cambrian age described from Queen Louise Land in latitude 76° 20′ N.[1] The Petermann quartzites also show a general resemblance to certain members of the Eleonoren Bay Formation which are typically developed to the east in the fjords; this Formation has been separated by Dr. Koch from the Franz Josef Beds and defined by him as appertaining to the pre-Cambrian (see p. 148). It is significant that the current-bedded and ripple-marked quartzites of the Petermann Series find a better parallel in the Queen Louise Land sediments than in the Eleonoren Bay Formation, and thus it seems advisable to suggest a correlation of the Petermann Series and the Queen Louise Land sediments. It is possible, however, that future exploration, especially of the unknown mountain country lying between the

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[1] *Medd. om. Grønland,* vol. lxxiii, p. 52, 1929.

Waltershausen Glacier and Queen Louise Land, may demonstrate the approximate contemporaneity of all three groups or regions of presumed pre-Cambrian beds.

Mention has already been made that in the fjords the Franz Josef Beds are thrust from east to west over the underlying Metamorphic Complex (see p. 148 and Fig. 1). The occurrence of the sedimentary Petermann Series on the west of the Metamorphic Complex implies the presence of folding or thrusting on a grand scale, and this view would be strengthened should the Petermann Series prove to be contemporaneous with any portion of the Eleonoren Bay Formation developed to the east. The route to Petermann Peak passed over a large granite batholith which locally obscured the eastern junction between the Petermann Series and the Metamorphic Complex. Nothing is known of the western junction of the Petermann Series, but it is certain that the sediments are underlain to the west by metamorphic rocks comparable with the Metamorphic Complex. Evidence in support of this is afforded by the north median moraine of the Nordenskiöld Glacier, which is built up of garnetiferous mica schists and kyanite schists ; since it originates from the mountains to the west of Petermann Peak, then these must in part be composed of metamorphic rocks (see Plate X and Fig. 2).

The *greyish-white granite,* which was found in the regions of the Disa and Nordenskiöld Glaciers, crops out over an area of about sixty square miles. Looking across the Nordenskiöld Glacier from Corner Lake, the cliff-section to the north shows great masses of dark-brown sedimentary rocks totally enclosed and " floating " in the granite (see Plate VIII, Figs. 1 and 2). Elsewhere, sedimentary rocks of the same appearance had been found to be quartzites, and it is almost certain that the included sediments are of comparable nature. Later, on the return of the climbing-party to the base in Kjerulf Fjord, the ship approached the bottom end of the Nordenskiöld Glacier, and the eastern end of the cliff-section mentioned above was visible. Although the light was bad, the dark inclusions could be seen at a distance of seven miles ; it was noticed also that the conical tip of Nathorst Peak consists of dark-brown rocks underlain by granite.

The eastern boundary of the granite was seen in the *Ptarmigan Glaciers* district (see Fig. 2). The Lower Ptarmigan Glacier, which enters the Nordenskiöld Glacier at Corner Lake, passes through granite in its lower reaches, and on the eastern side the granite is intrusive as stringers and veins into schists belonging to the Metamorphic Complex. The icefalls on the north side of the Upper Ptarmigan Glacier sweep north-westwards around a buttress of granite, while above Camp IV the ridge constituting the Battlements consists of mica schists and granite gneisses, intruded by granite at the south-west end.

Little variation of the granite was noticed in the field, and the following description of one specimen is therefore sufficient.

(102) Greyish-white biotite-muscovite granite, from screes above Camp IV, Upper Ptarmigan Glacier. (Fig. 4A.)

In hand specimen, large crystals of orthoclase are seen to include biotite often orientated with the basal plane parallel with the orthopinacoid of the felspar. The groundmass consists of interlocking micas, among which biotite predominates, quartz, and felspar, while pale-green zircons are occasionally large enough to be noticeable.

In thin slice, orthoclase occurs commonly in large twinned crystals, and in smaller untwinned crystals often displaying a central sericitized region surrounded by water-clear orthoclase. A little micrographic intergrowth is present. Almost as abundant as the orthoclase is microcline, and this shows microperthitic structure. It is of late crystallization as it includes orthoclase and more rarely quartz. Plagioclase felspar referable to acid oligoclase is present. Quartz exhibits allotriomorphic form and when included within microcline it is usually rounded. Biotite is remarkably fresh but occasionally shows a little chloritization, and this alteration is accompanied by the liberation of magnetite and acicular rutile. Muscovite is also present, but not in such quantities as biotite. Of the accessory minerals there is a little primary magnetite and abundant apatite, while numerous zircons give rise to pleochroic haloes when included in biotite. A chemical analysis is given below (specimen No. 103).

Biotite-muscovite granite, II. 4.1.2. Ridge above Camp IV, Upper Ptarmigan Glacier. The granite is rich in biotite. Analysis by Walter C. Hancock, B.A., F.I.C. :—

	%
SiO_2	66·57
Al_2O_3	11·42
Fe_2O_3	3·30
FeO	3·68
MgO	1·38
CaO	3·14
Na_2O	1·87
K_2O	6·32
H_2O above 105°	·25
H_2O at 105°	·20
CO_2	·20
TiO_2	·78
ZrO_2	trace
P_2O_5	1·02
F	·06
V_2O_3	trace
MnO	·10
CoO & NiO	trace
	100·29
Less O equivalent of F	·03
	100·26

On the south side of the Nordenskiöld Glacier near Camp V pegmatite-veins were encountered traversing the granite.

(98) Granite pegmatite with beryl; south side of Nordenskiöld Glacier near Camp V.

A coarse-grained rock containing massive quartz, felspar, greenish muscovite, and beryl crystals up to three inches in length.

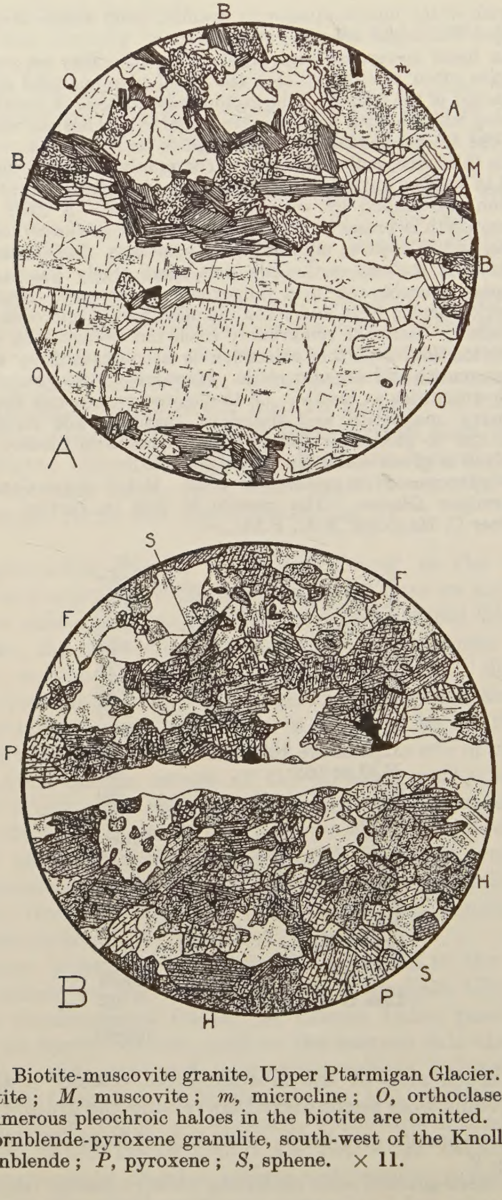

Fig. 4.—A. Biotite-muscovite granite, Upper Ptarmigan Glacier. *A*, apatite; *B*, biotite; *M*, muscovite; *m*, microcline; *O*, orthoclase; *Q*, quartz. The numerous pleochroic haloes in the biotite are omitted. × 11.
B. Hornblende-pyroxene granulite, south-west of the Knoll. *F*, felspar; *H*, hornblende; *P*, pyroxene; *S*, sphene. × 11.

Microscopically, the felspar is found to be oligoclase in which the twin lamellae have been much distorted. The large quartz areas do not show undulose extinction.

(97) Biotite-muscovite granite with pegmatite contact; south side of Nordenskiöld Glacier near Camp V.

This shows little difference from the above mentioned rocks, but flakes of white mica are included within certain acid oligoclase crystals in the granite, and are orientated parallel to the cleavage directions in the felspar; such mica is secondary, and is probably due to hydrolysis. The quartz in the pegmatite occurs in two habits; in large areas and in a mosaic distributed in veins.

The age of the granite is at present unknown, but it may have been intruded about the time of the Caledonian movements. An outstanding feature of the granite is the little altered character of the felspar and biotite; as the specimens were collected from loose blocks or from the surfaces of outcrops, their freshness may be attributed to the almost complete absence of chemical weathering under polar conditions.

IV. THE SENTINEL PEAK, RIDDAR VALLEY REGION.

In this region all the rocks examined were found to belong to the Metamorphic Complex, which extends eastwards along the fjords until it is covered by the overthrust Franz Josef Beds. A collection of specimens of the Complex was made in the fjords, and will be described by Dr. C. E. Tilley.

Sentinel Col: Mercanton Glacier.

At Sentinel Col garnetiferous mica gneisses are developed, and are associated on Sentinel Peak with kyanite schists. Below the Peak on its south-east side, granitic and micaceous gneisses crop out. Similar rocks characterize the screes on the south-west of the Knoll, and here hornblende-pyroxene-granulites are also found.

(104) Hornblende-pyroxene granulite from screes south-west of the Knoll.

A granulitic rock containing much hornblende, and about equal quantities of a pale jade-green pyroxene and white felspar (Fig. 4B). The felspar ranges between acid andesine and acid labradorite. There is little magnetite and abundant sphene. The sphene was probably formed from a titaniferous augite, and the granulite appears to have resulted from the metamorphism of a basic igneous rock. There is a small amount of apatite.

(105) Garnet-muscovite-biotite gneiss from Sentinel Col.

Two types of garnet are visible in thin slice. The mineral is either present as authigenic porphyroblasts, or as small irregular grains containing no inclusions (Fig. 5A). The porphyroblasts are characterized by an outer ring of garnet almost free of inclusions, inside which is a region extraordinarily rich in inclusions showing some semblance of a parallel orientation; the inclusions are rutile, magnetite, biotite, muscovite, felspar, and quartz. The porphyroblasts are traversed by sub-parallel parting-planes induced by foliation. The felspars are represented by orthoclase and oligoclase, while quartz occurs in abundance. Muscovite and biotite are intergrown, and both include small garnets, magnetite, and tourmaline; the latter is bluish-brown to brown in colour and usually euhedral. Disseminated throughout the rock are small sections of kyanite, slightly bluish-grey in colour.

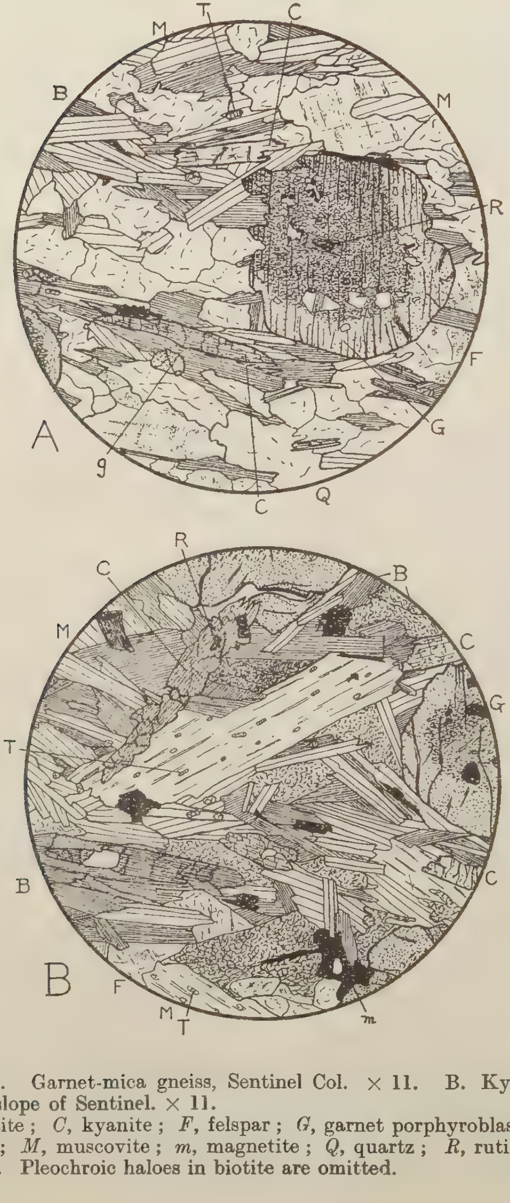

Fig. 5.—A. Garnet-mica gneiss, Sentinel Col. × 11. B. Kyanite schist, south slope of Sentinel. × 11.
B, biotite; *C*, kyanite; *F*, felspar; *G*, garnet porphyroblasts; *g*, small garnet; *M*, muscovite; *m*, magnetite; *Q*, quartz; *R*, rutile; *T*, tourmaline. Pleochroic haloes in biotite are omitted.

(106) Kyanite schist from the south slope of the Sentinel. (Fig. 5B).

A coarse-grained rock consisting of blades of kyanite and porphyroblasts of red garnet set in a mass of mica flakes. In thin slice, kyanite is almost colourless, and includes rounded rutile grains, irregular zircons, minute brownish tourmaline, magnetite, biotite, and muscovite. Biotite and muscovite are very abundant, and the latter includes euhedral tourmaline, which shows no differences from the tourmaline included in the kyanite. Authigenic porphyroblasts of garnet show a little cracking due to foliation, and exhibit an outer clear brim surrounding a core with numerous inclusions. These are present as finely divided indeterminate matter arranged in lines sometimes cutting across parting-planes, or as single masses of magnetite, rutile, muscovite, and felspar. Quartz is not abundant in the rock, while the felspars are represented by orthoclase and oligoclase but only in relatively small amounts.

Outlook Peak.

Gneisses were noted at the col between Snow Dome and Outlook Peak, at Outlook Col, and at Camp II. On the west ridge of Outlook Peak the gneisses are very coarse-grained and carry large garnets.

(107) Garnet-biotite-muscovite gneiss from west slope of Outlook Peak.

The rock is rich in micas and occasionally carries large red garnets; it is traversed by lit-par-lit veins of felspar and quartz which impart a coarse-grained appearance to the rock. Under the microscope, the melanocratic part of the rock is composed of biotite, muscovite, garnet, and abundant quartz; less common minerals are magnetite zircon, and apatite. The garnets occur as numerous small rounded grains, or as larger masses characterized by double refraction and many fractures. The lit-par-lit veins are almost entirely composed of orthoclase, albite, and quartz.

Riddar Valley.

The route between Camp I and the foot of the Riddar Valley lay across massive screes formed from the south flank of Riddarborgen; on the mountain itself are found biotite gneisses often abundantly rich in garnets. As seen from the opposite side of Kjerulf Fjord, the south-eastern cliff of Riddarborgen shows a remarkable recumbent fold, a section of which can be seen for nearly 4,000 feet. The fold is bounded above by a thrust-plane tilted up to the south-east.

V. CONCLUSION.

The main geological result obtained from the country in the Petermann Peak region is the repetition in the west of metamorphic and ancient sedimentary rocks, which are similar in many respects to the Metamorphic Complex and Eleonoren Bay Formation observed farther east in the fjords (see Fig. 1). Earth-movements of considerable importance seem necessary to explain this repetition, and the evidence indicates that such movements were in all probability of Caledonian age. The frontal margin of the Caledonian mountains may extend north at least as far as Queen

Louise Land, and may reach the sea in a southerly direction to the south of Scoresby Sound, somewhere in the unexplored region round Kangerdlugssuaq. The trend of this frontal margin suggests that it is the northerly continuation of the Caledonian Front already determined on the eastern side of North America, which passes under the sea off the coast of Newfoundland.

Our thanks are due to the different members of the Expedition who collected specimens and supplied notes upon which the above account is based, to Professor W. W. Watts in whose Department the work has been done, and to Dr. A. Brammall and Mr. A. A. Fitch for assistance with petrological problems. We are also indebted to the Commissioners for the Exhibition of 1851 for permitting one of their students to go to East Greenland, and to the Royal Society for the award of a Government Grant.

EXPLANATION OF PLATES VIII–X.

PLATE VIII.

FIG.

1.—Panoramic view looking north across the Nordenskiöld Glacier from Corner Lake. Note the dark sediments "floating" in the light granite at the east (right) end of the cliff, and also the granite contact towards the west (seen also in Plate VIII, Fig. 2). Extent of view about 14 miles.

2.—View north-west from Middle Ptarmigan Glacier across the Nordenskiöld Glacier to Petermann Peak. The junction between the granite and the Petermann Series is seen to the west (left) of the small, narrow glacier in the mid distance. (Compare Plate VIII, Fig. 1.)

PLATE IX.

1.—Banded Petermann Series on the west side of the Gregory Glacier.

2.—View north-west from the Battlements overlooking the Nordenskiöld Glacier; Little Petermann is on the north side of the glacier. Note the rockfall on the south side, and the junction of the granite (light) and the Petermann Series (dark) near the rockfall.

PLATE X.

Panoramic view from the south-west ridge of Petermann Peak, extending from the ice-cap on the west (right) to the cliffs on the south side of the Nordenskiöld Glacier. Note the origin of the south median moraine from a nunatak, and the north median moraine from mountains obscured by the ridge of Little Petermann (see p. 152). Little Petermann and the cliffs on the opposite side of the Nordenskiöld Glacier show bedded Petermann Series. Extent of view is about 25 miles.

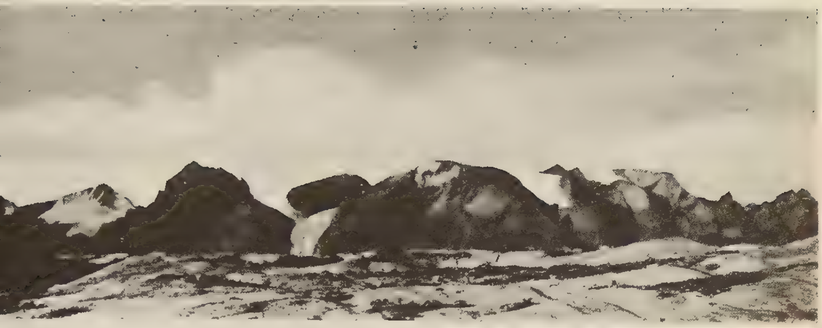

Fig. 1.

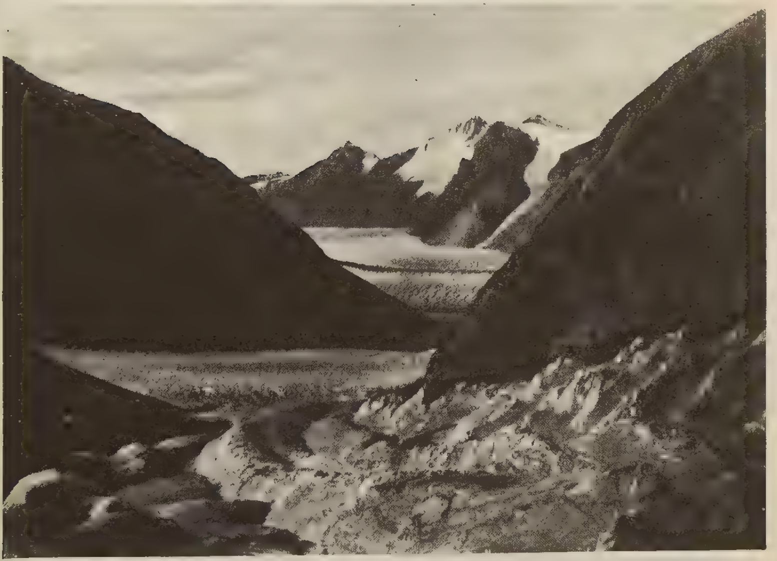

Fig. 2.

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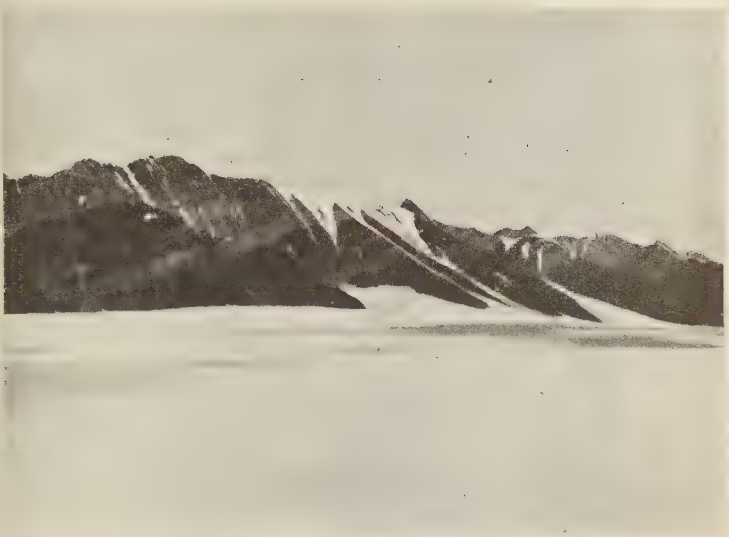

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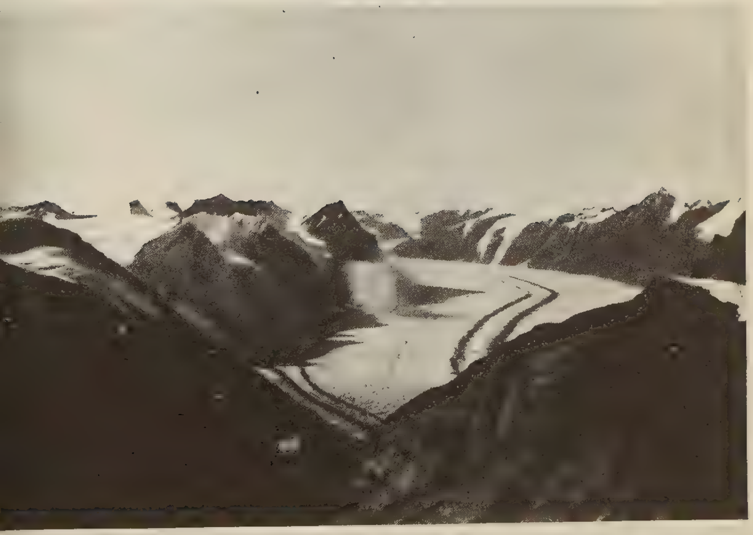
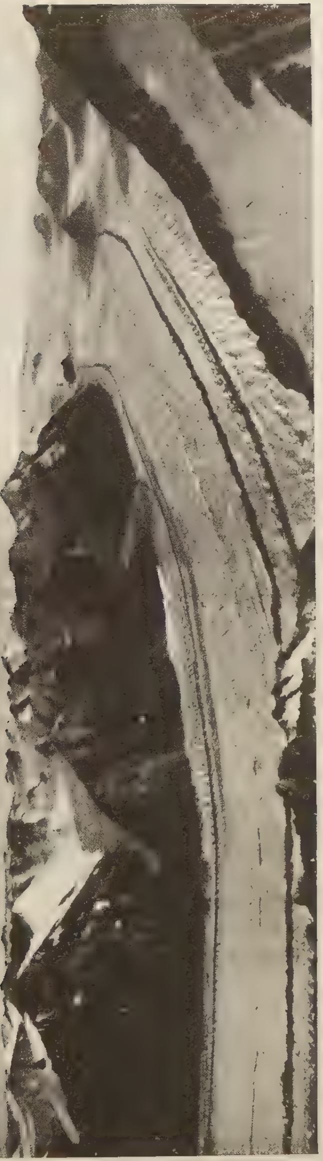


Fig. 2.



The Grading of Dune Sand by Wind.

By W. H. Barrett, The Science Schools, Harrow School.

THE samples to be described in this paper were taken from a small bay on the north coast of Sutherland called Traigh Allt Chailgeag on the Ordnance map. This bay is about three miles east of Durness, and one mile west of the mouth of L. Eireboll. It is eroded in gneiss, and is fed by a small stream at either end of the bay.

In an angle of the cliff in the middle of the bay the sand has been blown up against the cliff, so that there is a continuous slope of sand rising steeply to the top of the cliff at a height of about 50 feet.

This sand must have reached its present position as blown sand from the sea shore. The examination, therefore, of samples taken at different heights up the slope together with specimens from the shore was undertaken to see if it was possible to trace any definite grading action up the slope due to the combined effects of wind and gravity.

Sample No. 1 was taken from the top of the slope, and the remainder in numerical order at equal distances down the slope, No. 6 being taken from the bottom. Sample No. 7 was taken from the shore between tidemarks, and No. 8 for comparison from Rispond Harbour at the mouth of Loch Eireboll a mile or so to the east.

Treatment of Samples.

Each sample of sand in turn was well washed on a large filter and dried. A portion of this washed sand was kept for reference and the remainder subjected, part to mechanical analysis, and part to heavy liquid separation to isolate the heavy minerals. In each case the sand was first treated with dilute hydrochloric acid, well washed and dried. The loss in weight during this treatment is assigned to calcium carbonate (which a quick microscopic examination suggests to be principally in the form of shell fragments).

Mechanical Analysis.

The grading of each sample of sand was determined in a single vessel elutriator of the pattern described by Boswell.[1] Duplicate determinations were made on most of the samples. The results of these determinations are shown in Table 1. This table shows the percentage weight of each grade and the grade size (diameter of particles in mm.) for the six samples taken from the slope (1–6), and the shore sample (7). From these figures it is seen that the samples are similar in mechanical composition and well-graded—the bulk of sand particles lying in each case between 0·2. and 0·4 mm. diameter. It seems to be impossible, from these figures, to deduce any definite sorting action of the wind up the slope as far as size

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[1] *Monograph on Glass Sands*, 1918, pp. 25–6.

TABLE 1.

Mechanical analysis of Sands.

Grade size.	Sample No.						
Diam. in mm.	1	2	3	4	5	6	7
	%	%	%	%	%	%	%
——→ 0·10 .	0·2	0·1	0·05	0·3	0·1	0·01	0·0
0·10 → 0·20 .	10·3	6·6	4·8	11·0	6·3	6·9	6·8
0·20 → 0·23 .	11·3	14·3	8·9	12·8	15·7	10·6	8·7
0·23 → 0·26 .	14·0	44·1	34·7	29·3	34·4	37·7	25·6
0·26 → 0·30 .	34·2	17·0	23·1	28·5	12·6	22·5	25·1
0·30 → 0·40 .	28·9	17·0	26·9	17·5	29·4	21·4	32·7
0·40 ——→ .	1·1	0·9	1·5	0·6	1·4	0·7	1·0

of particle is concerned. These results are shown graphically in Fig. 1, where the cumulative percentages above each grade size are plotted against the logarithm of the grade size. Actually the separate curves lie so close together that it is impossible to show them all in a small scale diagram so that only the two extreme curves are shown, all the others lying between these two.

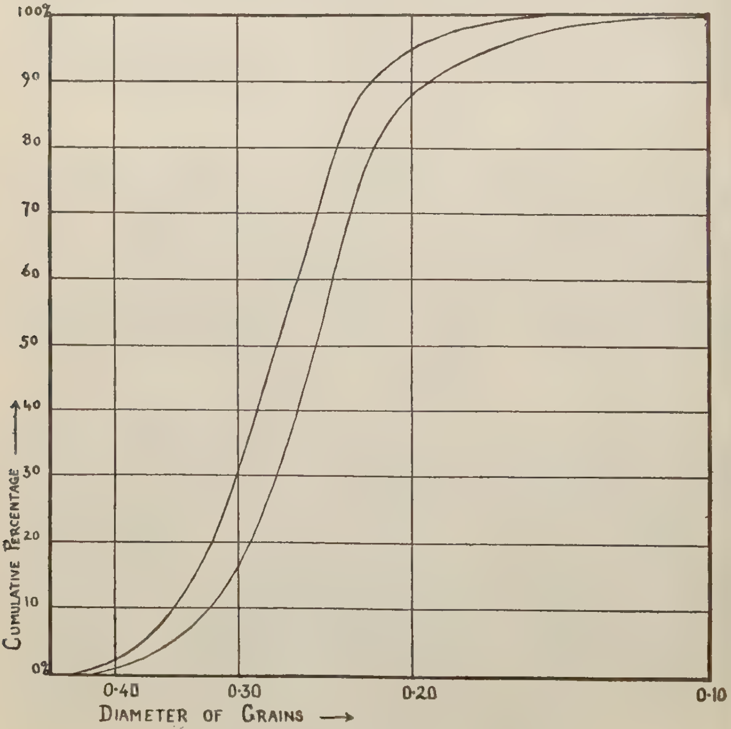

Fig. 1.—Curves showing grading of sand.

Distribution of Heavy Minerals.

The proportion of heavy minerals showed much more promising results than the mechanical grading. 20 gram portions of the washed sand were dried, weighed, and treated with hydrochloric acid to remove the calcium carbonate. A second washing, drying and weighing followed, and the loss in weight from this treatment is recorded in Table 2 as percentage of calcium carbonate. The residue from this treatment was separated into two crops by means of bromoform ($\Delta_{4^\circ}^{16^\circ} = 2{\cdot}87$). The heavy crop was well washed with benzene, dried and weighed. In view of the small quantity of heavy crop actually handled special precautions were taken in its manipulation and the weights were standardized before use. Moreover, the separations were always made at the same temperature (16° C.). The percentages of heavy minerals determined in this way are given in Table 2. As will be seen, the percentage of heavy minerals increases steadily as we pass from the top to the bottom of the slope. It is interesting to note that the average percentage of heavy minerals in Samples 1–6 is 0·50%, which is practically identical with the percentage in the shore sand. The constancy of the calcium carbonate in the slope samples is also rather striking.

TABLE 2.

COMPOSITION OF SANDS.

		Sample No.	*% of Calcium Carbonate.*	*% of Heavy Minerals.*
Traigh Allt Chailgeag	Sand slope.	1	33·5	0·34
		2	32·1	0·40
		3	32·6	0·38
		4	32·2	0·40
		5	34·2	0·70
		6	33·1	0·83
	Shore	7	42·2	0·48
Rispond Harbour		8	24·7	0·67

It is suggested, by these figures, that, up a steep slope, the wind exerts a certain sorting effect, sweeping the bulk of the sand more easily up the slope than the heavy particles, so that on passing up the slope the heavy mineral content diminishes, rapidly at first and then more slowly.

That the sorting action of the wind depends on the density only of the particles and not on the size is shown by examining the distribution of the heavy particles over the different sand grades. This was done with samples 2 and 6 by separating each grade with bromoform into a light and a heavy crop—the heavy crop being very carefully filtered off, washed, dried and weighed.

The degree of accuracy of these determinations is certainly not greater than 0·5% owing to the small quantities of heavy minerals obtained from the largest and smallest grades. The figures in the table are, therefore, only given to the nearest whole number per cent. The table shows the percentage of the total heavy crop present in each grade. Obviously the grading of the heavy minerals has not been affected by the wind transport, and the diminution in the amount of heavy minerals in samples nearer the top of the slope, therefore, affects equally heavy particles of all sizes, and is due to their greater density.

TABLE 3.

Distribution of Heavy Minerals over Different Grades.

Grade Size. Diam. in mm. . .	0·10–0·20	0·20–0·23	0·23–0·30	0·30–0·40	0–40-—
% Heavy Minerals in Sample 2 .	9	12	51	27	1
% Heavy Minerals in Sample 6 .	11	15	46	27	1

The work is being continued with samples from other localities. The author is indebted to Mr. D. M. Reid for the collection of the samples described.

Species of the Genus *Dimorphoceras* in the Bowland Shales.

By E. W. J. Moore, B.Sc.

THE genus *Dimorphoceras* was instituted by Hyatt, the genotype being *Goniatites gilbertsoni* (Phillips). The shells are involute and compressed, having the umbilicus very small or closed. The test shows fine lines of growth and a deep hyponomic sinus. *Dimorphoceras* is differentiated from other goniatites by having either one or both of the sutural lobes sub-divided by a small subsidiary saddle. Specimens are not generally abundant; and owing to the feeble ornamentation of the test, distinction between species is impossible unless uncrushed specimens showing sutures are obtained.

In the following paper an attempt is made to assign definite horizons and localities to the species. The three best known species are *D. gilbertsoni*, *D. discrepans* and *D. looneyi*. These are all found in the Bowland Shales, although the last two occur in the Sabden Shales also. The separation can only be made by means of suture lines, and the following descriptions are based on specimens that, with one exception, have been collected by myself.

D. gilbertsoni. Fig. 1.

1836, *Goniatites gilbertsoni*, Phillips, *Geol. Yorks.*, plate xx, figs. 27–31.

Size.—The largest I have found has a diameter of 21 mm. The dimensions of two other specimens are

	(*a*)	(*b*)
Diam.	17 mm.	15 mm.
Thickness	6·5 mm.	6 mm.

The umbilicus is minute.

The fine transverse striae bend forward on leaving the umbilicus and then back. They swing sharply forward again and back to form a deep hyponomic sinus over the venter. A shallow sulcus is formed on the latero-ventral shoulder.

The suture line shows one auxiliary saddle on the ventral lobe. This feature apparently begins to be formed at about 3·5 mm. diameter, as one of two specimens of this size shows the subsidiary saddle while the other does not. The median saddle is about two-thirds the height of the external saddle.

Horizon.—This species is found at the base of the section at Dinckley Ferry, on the River Ribble. Bisat (*Congrès de Stratigraphie Carbonifère Heerlen*, 1927, p. 123) suggests a band containing *Goniatites crenistria* and *Beyrichoceratoides truncatum* as the base of the Bowland Shales and the specimens of *D. gilbertsoni* occur a few feet below this band. Poorly preserved specimens are also found just above this *crenistria* band, which are probably *D. gilbertsoni*. I have also found this species in Swardean Clough, above Pendleton village, and in Burst Clough, Pendle.

D. gilbertsoni has been recorded at Instow and at Mouth Mill, in North Devon, associated with *Gastrioceras listeri* and *G. carbonarium*, which horizon would be equivalent to the Lower Coal Measures of Lancashire. The specimens from these localities do not show the sutures at all clearly. The best specimens I have collected from Mouth Mill show no sign of the subsidiary saddle and seem to indicate the form of *Anthracoceras* that occurs with *G. listeri* and *G. carbonarium* form the L.C.M. of Lancashire, although the sutures are somewhat indistinct. It thus appears that the reference to the Devonshire specimens is erroneous.

On this assumption the limits of this species seem to form a few feet below to a few feet above the base of the Bowland Shales.

D. gilbertsoni var. Fig. 2.

Diameter about 11 mm., thickness 4 mm. This specimen, found in Swardean Clough, differs from the type in :—

(*a*) The median saddle being higher and broader ;

(*b*) The subsidiary saddle forming rounded junctions with the external lobe, whereas in the type one of these is pointed.

The horizon is apparently above that of the type.

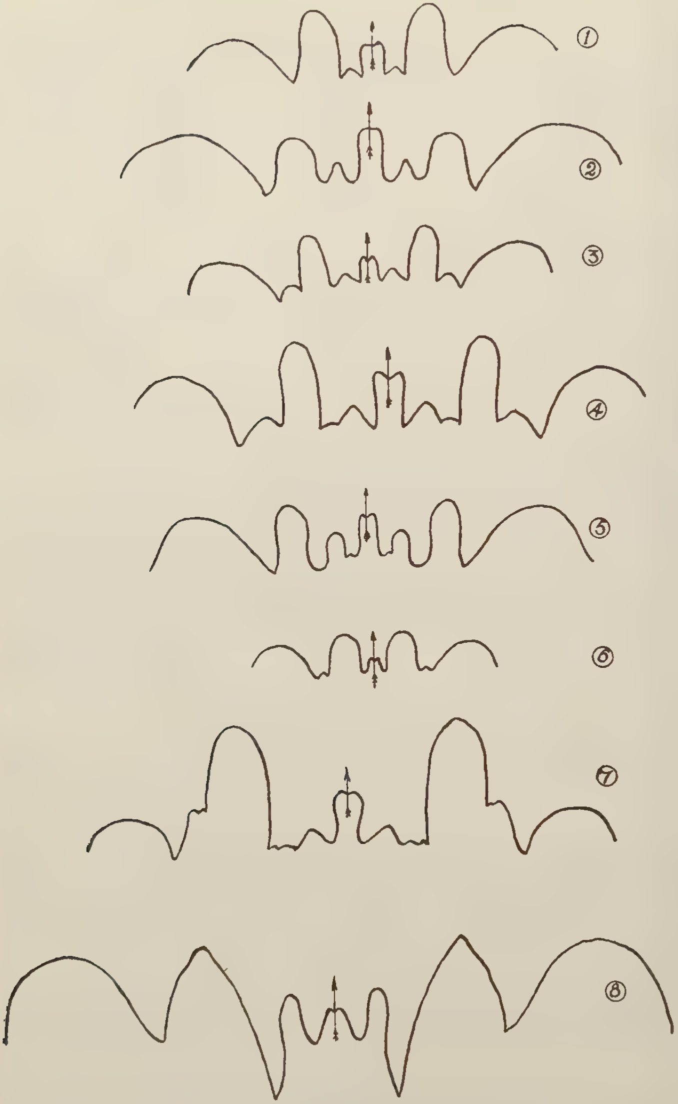

FIG. 1.—REFERENCES TO SUTURE LINES.

1. *D. gilbertsoni.* × 2.
2. *D. gilbertsoni* var. × 2.
3. *D. discrepans.* × 2.
4. *D. looneyi.* × 4.
5. *Dimorphoceras*, species A. × 2.
6. *Dimorphoceras*, species B. × 2.
7. *D.* aff. *denticulatum.* × 2.
8. *N. hawkinsi* (sp. nov.). × 2.

D. discrepans. Fig. 3.

1849, T. Brown, *Foss. Conch.*, p. 28, plate xxi, figs 8 and 15.

The diameter of the largest specimen I have found is 23 mm This specimen shows transverse striae passing in a forward direction from the umbilicus for 3 mm. and then swinging back 6 mm. The striae swing forward again about 2 mm. and at the latero-ventral shoulder curve back and form a sinus 6 mm. deep over the venter. There is a shallow sulcus at the latero-ventral shoulder. The suture differs from that of *D. gilbertsoni* in that the lateral lobe has a small auxiliary saddle.

In one specimen from Little Mearley Clough no subsidiary saddles are visible at a diameter of 2 mm., but another specimen shows both lobes acquiring the subsidiary saddles at about 3 mm.

A specimen, diameter 3 mm., from Dinckley shows the auxiliary saddle to be developed three sutures earlier on the external than on the lateral lobe.

Horizon.—The lowest beds in which I have found this species is about 20 ft. below *G. falcatus* in Little Mearley Clough. The range is great, as it extends high up into the Sabden Shales. I have found it at Dinckley Ferry in the *spiralis* beds and in the Sabden Shales on the River Darwen near Samlesbury Bottoms and at Roughlee.

A specimen obtained by Mr. Bisat in the zone of *Eumorphoceras pseudobilingue* at Malham, shows the ordinary *discrepans* suture up to a diameter of 12 mm. At a diameter of 13·8 mm. the external lobe develops a break in the subsidiary saddle while in the lateral lobe are two extra subsidiary saddles, very narrow and pointed. The suture figured by Foord and Crick (*B.M.N.H. Cat. Foss. Ceph.*, vol. iii, p. 223, fig. 106) is from a specimen of 10·5 mm. diameter. It may be that the extra complications in the suture are normal to all specimens in old age or to old specimens from the higher horizons. It cannot be regarded as showing transition to *D. looneyi* since the shape of the extra saddles is very different from that in this species.

D. looneyi. Fig. 4.

1836, *Goniatites looneyi* (pars), Phillips, *Geol. Yorks*, pt. ii, pl. xx, figs. 35 and 33.

This species is slightly stouter than those previously described and has two subsidiary saddles in the external lobe and one in the lateral.

Diameter 6·1 mm., thickness 4·2 mm.

My specimen is entirely septate and shows no test, but the cast shows obscure transverse striae which indicate a fairly deep hyponomic sinus, even at so small a diameter.

The suture line at a diameter of 5 mm. shows the external lobe with only one subsidiary saddle. The suture line figured is at 6 mm. diameter.

Horizon.—This specimen was collected at Whinney Gill, Skipton, above the beds containing *Goniatites newsomi* and below or at the base of the *E. pseudobilingue* beds. The range is apparently great as this species is also found in the Sabden Shales.

Dimorphoceras, Species A. Fig. 5.

Diameter 13 mm., thickness 5·5 mm.

Test not seen. The lateral lobe is entire but the external is divided by two subsidiary saddles. The one nearer the venter is small but the other is relatively large, being about half as high as the external saddle. It is rounded at the apex and constricted near the base. The second subsidiary saddle appears at about 6 mm. diam.

It is nearest to *D. gilbertsoni*, but differs in the large rounded subsidiary saddle and by the presence of a second saddle in the external lobe.

Horizon.—The only specimen of this form that I have seen was collected on the north bank of the River Ribble at Dinckley Ferry. The exact horizon is indeterminate since the block containing the specimen was not *in situ.* The material found in the drifted rocks at this spot suggests that its probable horizon is in the *spiralis* zone or just below it.

Dimorphoceras, Species B. Fig. 6.

Diameter 7·5 mm., thickness 5·6 mm.

Fragments of test visible show the usual bending of the transverse striae. The form is much stouter than is usual with this genus. The venter is rounded and a decided sulcus appears at the latero-ventral shoulder, becoming more pronounced with age.

Further, it differs from the other species described in its sutural characters, the external lobe being entire, except for the median saddle which is common to all goniatites, whereas the lateral lobe only has an auxiliary saddle.

Horizon.—Probably the *spiralis* zone. The specimen described was collected on the River Ribble at Dinckley Ferry.

Dimorphoceras aff. *denticulatum* (Schmidt). Fig. 7.

1924. *Die carbonischen Goniatiten Deutschlands*, pl. 22, fig. 19.

	(1)	(2)
Diameter	17·5	11
Thickness	10	6·2

The umbilicus is small, but there is a well-marked inner area. No test is clearly seen on either of my specimens, but the casts show obscure transverse markings indicating the deep hyponomic sinus that is characteristic of this genus. The suture shows a high median saddle. The external lobe is divided by a relatively large pointed subsidiary saddle, a second one about one-third as high as the first, and a third one which is minute. About half-way down, the lateral lobe is broken on its ventral side by a minute subsidiary saddle and one somewhat larger. The lateral lobe is pointed at its base.

In Schmidt's figure the sutural development is shown in four stages, and the suture of my specimen is nearest to the third given by Schmidt, although my specimen is apparently larger than his.

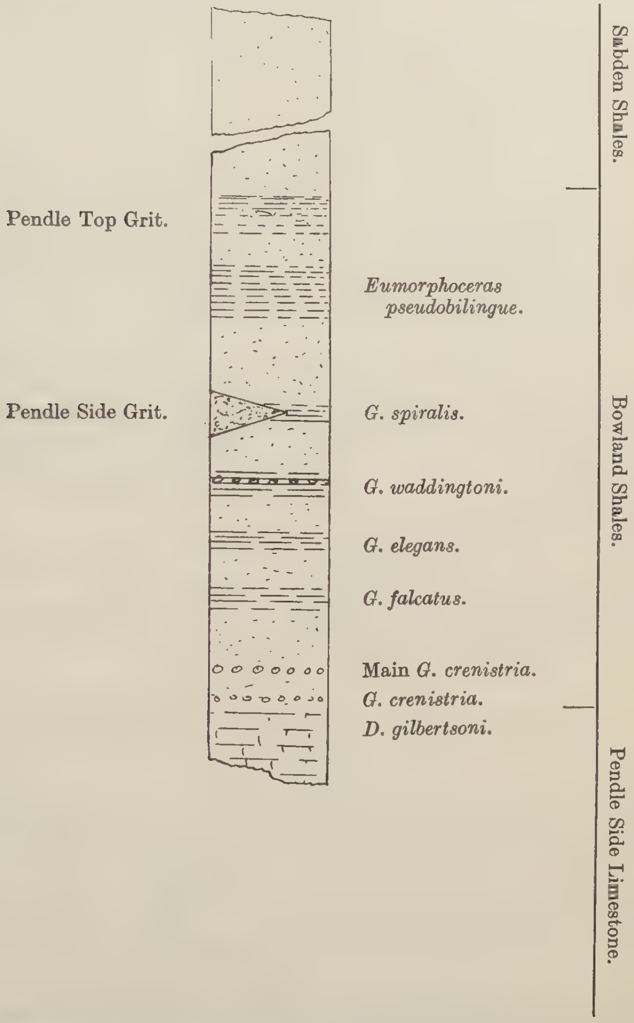

Fig. 2.—Section, not drawn to scale, of Bowland Shales and base of Sabden Shales.

Horizon.—The larger specimen was collected at Dinckley Ferry and is associated with *Goniatites newsomi* and *Sagittoceras meslerianum.*

Neodimorphoceras hawkinsi (sp. nov.). Fig. 8.

Diam. about 35 mm., thickness 12 mm.

Umbilicus minute.

The greatest thickness is close to the umbilicus. The sides of the shell are curved only slightly and the venter is acute. The test is ornamented with fine transverse striae which form a deep hyponomic sinus over the venter.

The median saddle of the suture line has divergent sides and is notched at the apex. The external lobe is divided by a parallel-sided saddle which rises higher than the median saddle. The external saddle and lateral lobe are acute and the lateral saddle sweeps in a curve to the umbilicus. This species shows affinities with the genus *Trizonoceras* (Girty, "Caney Shale of Oklahoma," *U.S. Geol. Survey Bull.* 377, 1909, p. 70) and with *D. texanum* Smith (*Carb. Amm. of Amer.*, plate xx, figs. 12–15).

Horizon.

The figured specimen came from the *spiralis* zone at Dinckley Ferry. Another smaller specimen was obtained from the Lower Sabden Shales, Gill Beck, near Colne. I have had the opportunity of comparing these specimens with C. 258 in the British Museum collection (Foord and Crick, *Foss. Ceph.*, part iii, p. 226), and although the suture line is not completely shown there is no doubt that it is the same species.[1]

In conclusion, I should like to thank Prof. Hawkins for reading the MS. and for his criticisms. The author alone is, however, responsible for any errors which may be present.

The specimens described in this paper are being deposited in the British Museum (Natural History).

An Association of Afwillite with Spurrite.

By C. E. TILLEY.

THE mineral afwillite ($3CaO.2SiO_2.3H_2O$) is so far recorded only from the Kimberley Mines (Parry and Wright, *Min. Mag.*, 1925, p. 277), where it occurs in association with natrolite, apophyllite, and calcite in a dolerite inclusion in kimberlite. Its occurrence with markedly different associations is sufficient warrant for a short record. Examination of the mineral associates of spurrite of the contact zone of the Scawt Hill dolerite Co. Antrim has revealed a second occurrence of afwillite, lining a cavity in a thin calcitic crust covering a spurrite contact rock.

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[1] Since the foregoing was written I have found a young specimen of *N. hawkinsi*. Diam. = 11·4 mm.; thickness = 4·6 mm. Umbilicus closed. The test, as seen in small portions preserved, is thin and marked with fine spirals, about six to the mm. over the venter, and slightly further apart over the sides. The external saddles have parallel sides, and curved pointed ends as in an arch. This feature agrees with that in the specimen from Gill Beck, where the external saddles in the younger part have less divergent sides than those in the older part of the shell. This specimen was found in the *G. subcircularis* band, Dinckley Ferry. (See *U.S. Geol. Surv. Bull.*, 544, pl. xxxv.)

The crystals are of microscopic dimensions, usually under $\frac{1}{2}$ mm. in size, and form clusters of sub-parallel individuals each of which is tabular in habit on 100 and elongated in the direction of the axis of symmetry **b** (Fig. 1). They are usually terminated by clinodomes 011 (possibly also 023 or 034), readily recognized by angular measurements of the trace of these planes for crystals lying flat on 100. The 100 faces are often bevelled by narrow orthodomes. This habit is distinct from that recorded for the original afwillite where the face 100 is inconspicuous.

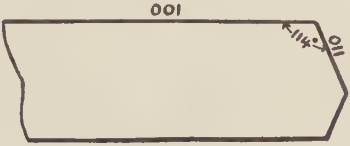

Fig. 1.

Crystals lying flat on the 100 face remain practically dark between crossed nicols, for they show the almost normal emergence of an optic axis (one optic axis includes an angle of 86·7° with axis c in the plane 010). The other distinctive optical features of afwillite are the close approximation of the refractive indices α and β—:(α 1·617, β 1·620, γ 1·632), and the extinction $X_{\Lambda}c = 30°$ in the plane 010 (Fig. 2). The mineral is decomposed by water and is alkaline to litmus, the constitution $2H_2CaSiO_4.Ca(OH)_2$ being indicated. The chemical relationship to spurrite $2CaCaSiO_4{\cdot}CaCO_3$ is clear; the close association and manner of occurrence of these two minerals show that they are genetically related, afwillite being a derivative of spurrite.

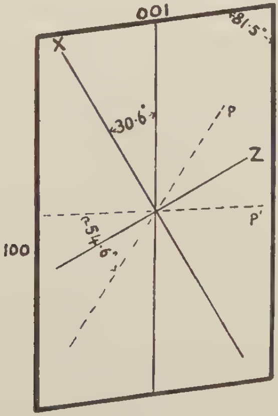

Fig. 2.

The Distinction between Chlorophaeite and Palagonite.

By Martin A. Peacock, B.Sc., Ph.D., M.A., Harvard University.[1]

In a recent paper, Dr. L. L. Fermor (12) discusses the composition of chlorophaeite and palagonite and the employment of these terms, with special reference to the present writer's view of this subject, reached principally through a study of the palagonite-tuffs of Iceland (11). In an earlier extended study of Indian traps Dr. Fermor had concluded that the orange and brown chlorophaeite-like bodies, often called "palagonite" by the Indian Survey petrographers, are identical with chlorophaeite, and that the similar associated greenish substance, also embraced in the term "palagonite" by these workers, is perhaps, when anisotropic, the chlorite delessite (10, p. 133). One inference from these observations is that palagonite comprises chlorophaeite and the associated green substance; another is that the application of palagonite to these bodies was primarily a misnomer.

Extending the former argument Dr. Fermor compares the available analyses of chlorophaeite with the composition of typical Icelandic palagonite, as roughly deduced from the analysis of palagonite-rock given by the present writer (11, p. 66), and shows that the composition of both materials may be approximately expressed by a general formula.

$$2\tfrac{1}{2}H_2O.\ 5R_2O_3.\ 20SiO_2+n\,(RO.\ H_2O)+(80-4n)\ H_2O,$$

where n takes various integral values approximately to satisfy the several analyses. From this it is concluded that chlorophaeite and typical Icelandic palagonite are chemically substantially similar. It is further argued that palagonitisation in the Icelandic tuffs differs from the process by which chlorophaeite is formed in degree rather than in kind; and that in any case mode of origin, whether known or deduced, forms no basis for separating materials which are essentially similar in composition. The conclusion is thus that Icelandic palagonite, the product of alteration, mainly by hydration, of the pure vitreous particles in dominantly glassy basaltic tufts, is identical with chlorophaeite; and that, therefore, the use of palagonite in this sense, the original sense of Sartorius von Waltershausen, sustained by the authors of the *Challenger Report* on deep-sea deposits and by the present writer, should be discontinued. Granting, however, that the term palagonite may still be useful in a more extended sense, Dr. Fermor recommends a reversion to the usage which followed Penck's destructive critical study of 1879 (2), and was also adopted by Dana (5). By this usage palagonite became a rock name synonymous with palagonite-tuff, signifying a dominantly vitreous basaltic tuff altered mainly by hydration. And, finally, Dr. Fermor proposes to retain the term palagonitisation to mean the process whereby vitreous basaltic tuffs are converted into palagonite-tuffs, and also the process by which chlorophaeite and the similar associated green material are formed.

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[1] Commonwealth Fund Fellow, from the University of Glasgow.

But the logical application of Dr. Fermor's findings leads to anomalous results. Chlorophaeite, it will be shown, properly comprises both the deep-brown and the associated green mineraloids; and, therefore, if palagonite, the product of alteration of sideromelane (ideal basaltic glass) mainly by hydration, is indeed identical with chlorophaeite, then we should describe palagonite-tuff and palagonite-rock as chlorophaeite-tuff and chlorophaeite-rock respectively. These names would suggest rocks containing notable amounts of the almost black, lustrous, pitch-like substance chlorophaeite. Nothing could be more misleading. Palagonite-tuffs contain abundant black, lustrous particles; but these are fragments of fresh, anhydrous sideromelane from which palagonite is formed by hydration. Palagonite, the alteration product itself, is usually brown in various shades, dull and powdery.

Again, to retain palagonitisation both as the process whereby sideromelane-tuffs are converted into palagonite-tuffs, and as the process by which chlorophaeite is formed, implies similarity between the two processes. Actually they are widely different. The palagonitised fragments of basaltic glass dredged by the *Challenger* originated from submarine eruptions, and sea-water effected the hydration of the glass fragments to form palagonite. The shelly Sicilian palagonite-tuffs, for which the term palagonite was originally proposed by von Waltershausen, represent basaltic ejecta which fell into the sea and similarly became palagonitised by the action of sea-water. In Iceland, palagonite-tuffs are products of basaltic volcanoes located beneath the Pleistocene ice-sheet; these produced fragmented material which was chilled to an obsidian-like glass (sideromelane) by contact with the overlying ice-sheet or the water produced by its local melting. The sideromelane-tuffs thus formed became palagonitised either by sea-water during a subsequent marine encroachment, by prolonged saturation with fresh water resulting from the melting of the overlying ice, or by the action of hot springs. In the Columbia River Plateau vitreous tuffs are formed by the contact of basaltic ejecta with surface waters, and palagonitisation has resulted from the steam thus generated (13, pp. 375–6). In nearly every case hydration selectively attacked the basaltic glass, leaving the ferromagnesian and felspathic microlitic content of the glass wholly intact. The resulting gel-like product, palagonite, has, with some modifications, substantially the composition of basalt to which about 20 to 30 per cent of water has been added; this gel is highly unstable, and crystallises readily with the formation of two complementary products, chlorite and zeolites. Thus, in every case palagonitisation in tuffs has been induced by water or water vapour of external origin, at low or moderate temperatures.

Chlorophaeite, on the other hand, according to every careful study, has been formed in doleritic rocks by the reaction of late-magmatic, therefore internal, fluids, with newly crystallised ferromagnesian minerals in the rock, most commonly olivine, or sometimes, perhaps, with ultrabasic vitreous residues of similar composition. The resulting gel-like product has thus a strongly basic composition corresponding roughly with that of a chlorite.

The misleading implications inherent in Dr. Fermor's proposed usage of the terms in question suggest that there is a fallacy in the argument leading to this proposal. The fallacy lies, it is believed, in placing exclusive emphasis on the rather slight chemical similarity between chlorophaeite and palagonite, each of which incidentally, varies rather widely in composition, and neglecting the wide and obvious differences in the appearance, occurrence and origin of the two materials. Analyses of chlorophaeite and one indirect estimate of the composition of palagonite can, it is true, be approximately embraced by the formula proposed by Dr. Fermor. But this formula also forms the basis of a proposed "chlorophaeite series" of minerals embracing, as Dr. Fermor shows, twenty other minerals, including such definite species as some zeolites and even biotite. Whatever the significance of this "chlorophaeite series" may be, the fact that one indirect estimate of the chemical composition of palagonite conforms with the general formula, does not compel us to accept the conclusion that chlorophaeite and palagonite are substantially alike.

In the following table all the available analyses of chlorophaeite are arranged together with two analyses of the so-called "palagonite" of similar appearance and occurrence. Analysis I represents the original Scottish type material. II is the Indian type from which Dr. Fermor's formula is derived. III is a recent analysis of typical material from a trachydolerite dyke in the Columbia River field. IV was described as "palagonite" by Emerson; but through Professor Emerson's kindness the present writer was enabled to study thin sections of this material and to confirm his belief, gained from the detailed published description (7) that it is chlorophaeite. V is Dr. Campbell's finely developed chlorophaeite from near Edinburgh, specimens and thin sections of which the writer was privileged to examine some years ago. VI is material called "palagonite" by Teall, but agreeing in all essentials with chlorophaeite. VII is material described as "aluminous chlorophaeite" by Heddle. All these materials occur as deuteric alteration products in basalts or dolerites.

It will be seen at once that the first three analyses, representing orange-brown chlorophaeite, agree closely among themselves; they conform very satisfactorily with the formula: $3R_2O_3.5RO.12SiO_2 + nH_2O$, where R_2O_3 is almost wholly Fe_2O_3, RO is preponderantly MgO, and H_2O varies, as we expect in a colloidal mineraloid, from 24 to 35. Alumina and the alkalis are practically absent, and iron is almost wholly peroxidized. If these three analyses are averaged with the chlorophaeite from Dalmahoy (V), as was done recently (13, p. 365), the simpler formula: $R_2O_3.2(R, R_2)O.4SiO_2 + 10H_2O$ is obtained; but the complicated formula of Dr. Fermor seems to attach unwarranted significance to the relative proportions of water released above and below 100° in a mineral of this kind.

In analyses IV to VII considerable divergencies are observed. Alumina shows a progressive increase; ferrous oxide fluctuates widely, usually with complementary variations in ferric oxide; and the alkalis appear in various small amounts. The explanation for this lies in the fact that brown chlorophaeite is commonly associated with a similar green material which may be an isotropic gel, as brown chlorophaeite commonly is, or may show fibrous crystalline structure. The green material has been shown to contain ferrous oxide (9, p. 439), and it is also probably aluminous. In the fibrous condition the green material may be delessite, as Dr. Fermor suggests; but if it were delessite, which carries about 20 per cent of MgO, we would expect a stronger increase of this constituent in analyses of chlorophaeite containing notable amounts of the green phase. In the gel condition the green phase cannot be further identified. If chlorophaeite were to be restricted to the brown material represented by analyses I to III, Dr. Campbell's perfectly

TABLE I.—ANALYSES OF CHLOROPHAEITE AND OF TWO SIMILAR MATERIALS CALLED "PALAGONITE".

	I.	II.	III.	IV.	V.	VI.	VII.
SiO_2	36·00	35·15	38·67	40·35	32·95	35·48	35·99
TiO_2	—	—	0·24	0·20	0·62	—	—
Al_2O_3	—	1·00	1·54	5·11	5·40	8·30	10·49
Fe_2O_3	22·80	21·77	26·14	24·99	12·37	12·30	11·89
FeO	2·46	2·18	2·06	3·55	9·18	14·60	1·63
MnO	0·50	0·35	0·31	0·22	0·33	—	0·08
MgO	9·50	5·02	6·77	5·48	4·75	7·10	10·52
CaO	2·52	2·51	1·72	1·32	3·05	1·04	5·15
Na_2O	trace.	—	0·00	0·18	1·68	3·92	0·76
K_2O		—	0·10	1·44	0·36	trace.	0·34
$H_2O +$	7·23	4·98	9·56	8·51	5·20	16·80	9·04
$H_2O -$	19·23	27·44	12·54	8·51	23·90		14·16
	100·24	100·40	99·65	99·86	99·79	99·54	100·05

I.—Sgurr Mor, Rum, Scotland; analyst, M. F. Heddle (3, p. 87).
II.—Nagpur, India: analyst B. P. C. Roy (10, p. 127).
III.—Grande Ronde Valley, near Anatone, S. E. Washington; analysts, Ledoux & Co. (13, p. 364).
IV.—New Reservoir, Holyoke, Massachusetts; analyst, G. Steiger (7, p. 112).
V.—Ravelrig Quarry, Dalmahoy, near Edinburgh; analyst, W. H. Herdsman (9, p. 438).
VI.—Cape Flora, Franz Josef Land; analyst, Teall (6, p. 485).
VII.—Giant's Causeway; analyst, M. F. Heddle (3, p. 88).

typical material (V) would have to be rejected. There is therefore no choice but to recognize that chlorophaeite, as the very word implies, comprises a brown phase and a green phase, the former carrying the ferric oxide of the analyses, and the latter holding the bulk of the ferrous oxide and probably also the alumina. From this it follows, not that palagonite comprises chlorophaeite and an associated green material believed to be delessite, but that the materials called " palagonite " in doleritic rocks are simply chlorophaeite, and that therefore the use of the term palagonite to describe these materials is unwarranted.

The persistence of this unfortunate use of palagonite is no doubt partly due to the weighty precedent the usage received in being adopted by Teall (6, pp. 485–6), and in recent years by the fact that Holmes' *Nomenclature of Petrology* (8) refers to Teall's work under the definition of palagonite. Teall's " palagonite " was apparently formed by magmatic hydration of ultra-basic vitreous residues in basalts from Franz Josef Land ; and since palagonite results from hydration of basaltic glass, the extension of palagonite to cover the hydrothermal basaltic product seemed logical enough. But in discussing the analysis of the new " palagonite " in relation to other palagonite analyses, Teall realized that his material differed from them in carrying 14·60 per cent of ferrous oxide, while palagonite is always practically free from that constituent. Realizing this, he wrote : " If this be taken as an essential character the present substance is certainly not palagonite . . . " (6, p. 486). Actually Teall's description and analysis suggest that his material is an aluminous chlorophaeite with abundance of the green phase which accounts for the high value of ferrous oxide. In concluding, in spite of the chemical discrepancy, that " no great harm will be done by extending the use of the term (palagonite) so as to include this substance " (loc. cit.), Teall implied misgivings which have proved to be amply well founded.

Attempts to prove or disprove any fine points from chemical analyses of true palagonite are futile, as the composition of palagonite is widely variable, depending both on that of the fresh glass, sideromelane, from which it is derived, and on the extent to which palagonitization of the glass has proceeded. Furthermore, palagonite is almost always so intimately associated with chips of the fresh parent glass and with products of its own decay, namely zeolites and chlorites, that the separation of a pure sample is practically impossible. Only one direct analysis of palagonite is available ; this is one by Sipöcz of the palagonite coating of a fragment of basic volcanic glass (sideromelane) collected by the *Challenger* Expedition. Even this analysis is not wholly satisfactory as the sample was dried at 105° before proceeding with the analysis. Fortunately palagonite from the same station was partially analysed by Dittmar who obtained 13·5 per cent of water at 100°. Assuming that 15 per cent of water was lost at 105° in Sipöcz's sample and converting his values accordingly, the resulting proportions, given under I in Table II, cannot be far from the truth. The next best analysis is that of an Icelandic example, by W. H. & F. Herdsman, given recently by the present writer (11, p. 66). The material is palagonite rock containing 76 per cent of palagonite, 14 per cent of clinochlore, 7 per cent of stilbite and faujasite, and 3 per cent of sideromelane of known composition. After making the appropriate allowances the composition of the palagonite itself is closely represented by the calculated values given under II in the table. Palagonite-tuffs have been analysed many times, but unfortunately these analyses are not accompanied by quantitative estimates of the various other constituents of the tuffs. Although these bulk analyses are not without value, they are open to the criticism which originally brought disrepute on the term palagonite, namely, that the analysed samples were impure.

The two analyses differ rather widely, and any formula which may be devised to embrace them can have but little value. The abundance of alkalis and manganous oxide in the deep-sea example is probably related to its marine origin; and the low value for lime in the same sample is perhaps due to the solvent effect of sea-water. But these variations do not obscure the essential chemical difference existing between palagonite and chlorophaeite, namely, that palagonite is little more than half as rich as chlorophaeite in the ferromagnesian oxides, and more than twice as rich in alumina. This difference is expressed quantitatively in the following table, the figures being based on the analyses given in Tables I and II.

TABLE II.—ANALYSES OF PALAGONITE.

	I.	II.
SiO_2	37·8	33·2
TiO_2	—	2·8
Al_2O_3	13·7	9·6
Fe_2O_3	12·3	13·3
FeO	—	1·6
MnO	2·5	0·3
MgO	1·9	2·3
CaO	1·6	8·0
Na_2O	3·8	0·0
K_2O	3·4	0·3
H_2O below 105°	15·0	20·6
H_2O above 105°	8·0	7·6
	100·0	100·0[1]

I.—Palagonite, lat. 13° 28′ S., long. 149° 30′ W., 2,350 fathoms, Pacific Ocean; calculated from Sipöcz's analysis (4, p. 463), assuming that 15 per cent of water had been lost at 105°.

II.—Palagonite, Hvalfjördur, Iceland; calculated from W. H. and F. Herdsman's analysis of palagonite-rock (11, p. 66).

	Chlorophaeite.	Palagonite.
Average (Fe_2O_3 + FeO + MnO + MgO)	31·3	17·1
Average Al_2O_3	4·5	11·6

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[1] Including P_2O_5, 0·3; S, 0·1.

Such a broad difference, amounting almost to the difference between an orthosilicate and a metasilicate, is in itself surely sufficient to form a basis for distinguishing these two materials, even although both are mineraloids of variable composition. And when we consider, furthermore, that this difference has also genetic significance, being a function of the difference between the composition of the respective parent materials, ferromagnesian minerals and perhaps sometimes ultra-basic vitreous residues in the case of chlorophaeite, and glass of normal basaltic composition in the case of palagonite, it seems necessary to abandon the contention that chlorophaeite and palagonite are chemically substantially alike, and therefore also any arguments based on this contention. Ideally palagonite is a gel with a colour and lustre rather like those of resin; and in this condition a slight resemblance to chlorophaeite, which is pitch-like, can be conceived. But gel-palagonite succumbs so readily to partial dehydration and incipient crystallization, that palagonite forming the matrix of vitreous tuffs such as those which form so important a component of the great Breccia Formation of Iceland, is most commonly a dull, whitish-brown, even earthy material as different from chlorophaeite as chalk is from cheese.

Where terms have been consistently used by competent workers in a manner which at once retains the meaning intended by the author of the terms, and also survives the test of subsequent studies of the materials in question, such usage claims prime consideration. In their detailed study of the deep-sea deposits collected by the *Challenger* Expedition, Murray and Renard consistently used palagonite, as von Waltershausen intended (1, pp. 203, 213), to describe the product of hydration of clear basic volcanic glass, for which they retained Waltershausen's term sideromelane. In a petrological study of the Icelandic tuffs the present writer found that, of the various ways the terms had been used, von Waltershausen's original meaning sustained by Murray and Renard, was the only satisfactory one; and in extension he suggested the addition of palagonitic tuff to mean a vitreous basaltic tuff in which palagonitization had just commenced, and palagonite-rock, as an equivalent of von Waltershausen's palagonitfels, to denote a tuff consisting largely of palagonite (11, p. 56). To revert to Penck's erroneous decision: "dass ein als Palagonit zu bezeichnender Körper nicht existiert" (2, p. 568), and again to use palagonite vaguely both as a synonym for palagonite-tuff and as a descriptive term for bodies which cannot be distinguished from chlorophaeite, would be to ignore the clear and simple original usage which after eighty years has proved entirely adequate, and to cause the meaning of the term to relapse into confusion.

To conclude, it is desirable to enumerate the main conclusions of the present discussion. To some extent these conclusions involve also the results of two previous studies (11, 13).

(1) The brown and green phases of chlorophaeite cannot be

systematically separated. The brown phase closely approaches the composition $3R_2O_3.5RO.12SiO_2 + nH_2O$, where R_2O_3 is almost wholly Fe_2O_3, RO is mainly MgO, and n varies from 24 to 35. With admixture of the green phase Al_2O_3 and FeO become prominent constituents and alkalis appear in small amounts.

(2) Chlorophaeite occurs in doleritic rocks by the reaction of magmatic fluids with ferromagnesian minerals, most commonly olivine, and perhaps sometimes with ultra-basic vitreous residues. The strongly basic character of chlorophaeite, which may be regarded as a potential chlorite, is thus related to its origin.

(3) The materials called "palagonite" in doleritic rocks are simply chlorophaeite.

(4) Palagonite is the hydration product of clear basaltic glass (sideromelane) at low or moderate temperatures. It occurs typically in dominantly vitreous basaltic tuffs formed under conditions of drastic cooling and subsequent prolonged saturation with water or water vapour.

(5) Occasionally palagonite has a resinous appearance; more often it is whitish brown and powdery, due to partial dehydration and incipient crystallization, and impossible to confuse with chlorophaeite which is pitch-like in hand specimens.

(6) With certain minor changes palagonite has substantially the chemical composition of basalt to which 20 to 30 per cent of water has been added. Palagonite is thus on the average little more than half as rich as chlorophaeite in the ferro-magnesian oxides, and more than twice as rich in alumina. Palagonite is potentially a mixture of chlorite and zeolites, and actually it breaks down readily to form such a pair of complementary products.

(7) Chlorophaeite and palagonite are therefore distinct in composition, in occurrence, in appearance and in mode of origin. The fact that materials called "palagonite" in doleritic rocks prove to be chlorophaeite shows only that the term palagonite has been unnecessarily and incorrectly used in this sense, and that if further confusion is to be avoided this misuse should be abandoned.

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On Certain Palaeozoic Bryozoa in the British Museum (Natural History).

By B. P. Nekhoroshev.

WHILE working for several years on Palaeozoic Bryozoa with the aim of establishing the Palaeozoic stratigraphy of the Altai Mountains on the basis of the Bryozoan faunas, I have always been aware of a great contradiction. The works of American authors showed clearly that the stratigraphic importance of the Bryozoa is not inferior to that of any other group of fossils,[1] whilst in the works of newer European authors the Palaeozoic Bryozoa were not only deprived of any significant rôle, but often even quite ignored. Owing to this, there arose a question whether the Palaeozoic Bryozoa have a universal distribution like, for instance, the Brachiopoda; or whether there is in North America a special Bryozoan fauna of stratigraphic importance locally, but absent from other parts of the globe. The study of the Siberian Palaeozoic Bryozoa showed a number of forms so far known only from North America, and this suggested that the apparent absence of "American" forms in the other parts of the globe is owing to the lack of intensive study given to the Palaeozoic Bryozoan faunas outside North America. Through the kindness of Dr. Nalivkin, who handed over to me several Bryozoa collected by him in the Middle Devonian of Germany, I was able to confirm this suggestion[2] and I decided to examine, if possible, the existing collections of Palaeozoic Bryozoa of Europe. This appeared the more necessary because, although Palaeozoic Bryozoa were originally described by European authors, yet the species described by them were quite ignored by later American writers. Clearly then, if a comparison of the European with the American

[1] 1900. Nickles and Bassler, *Bull. U.S. Geol. Surv.*, No. 173, p. 121.
[2] *Centralbl. f. Min.*, etc., Jahrg. 1928, Abt. B, No. 8, p. 476.

Palaeozoic Bryozoa were made, it would be likely that the trivial names of some American species would be replaced by the prior trivial names of European species. To make this comparison, I visited during the winter of 1928–9 some of the most important museums of Europe, in which I could find either the type specimens of the European Bryozoa, or merely rich collections of topotypes. A revision of the material contained in the museums of Berlin, Munich, Bonn, Prague, Paris and London wholly confirmed my view, namely, that the " American " forms of Palaeozoic Bryozoa were universally distributed, but hitherto had been described and figured, often quite incorrectly, as distinct genera.

I must note here that, having but little time at my disposal, I naturally did not attempt to compare the species, but restricted myself to generic comparisons of the European and American forms ; but these afforded sufficiently interesting results. Moreover, I was compelled to concentrate my attention exclusively upon the Bryozoa of the family Fenestellidae and upon forms closely allied in structure, since only in that group was it possible to make a cursory examination without the aid of microscopical preparations. There are very few of these in the European museums, and there was no time to prepare others.

The Palaeozoic Bryozoa are most fully represented in the British Museum of Natural History, where there are preserved not only rich collections of Bryozoa from Great Britain and Ireland, but also collections from various British colonies, those made on various expeditions, and, finally, a number of collections of Palaeozoic Bryozoa from other countries. Moreover, the importance of these collections is increased by their containing a large amount of material from those localities which yielded most of the European species described by Murchison, Phillips, M'Coy, King and others. Therefore, leaving the results of my observations in the other museums of Europe for a description in another paper, I shall dwell here with some detail only on those results which could be obtained on a cursory examination of the Palaeozoic Bryozoa preserved in the British Museum (Natural History).

It is my agreeable duty to acknowledge the kind attention paid to me by the Scientific Staff of the British Museum (Natural History) ; I am especially indebted to Dr. W. D. Lang, Keeper of the Geological Department of the Museum, for kindly allowing me to work in the Museum and to examine such material as interested me, as well as to Dr. H. D. Thomas, who furnished me with all the necessary apparatus, literature and specimens, and who gave me so much of his time and attention during the whole period of my work in the Museum.

I have revised the Ordovician, Silurian, Devonian, Carboniferous and Permian Bryozoa preserved in the Museum, and, further, I shall try in this paper to give brief characteristics of the Bryozoa of each of these systems, noting any points of special interest.

ORDOVICIAN BRYOZOA.

Judging from the collections examined, the Ordovician deposits are not very favourable for the study of Bryozoa. They are represented by argillaceous shales, often highly crumpled, and, moreover, eroded, and containing, in consequence, only the imprints of Bryozoa. It is impossible, therefore, to prepare thin sections, without which the internal details of structure cannot be studied.

In these deposits the networks of *Chasmatopora* (*Phylloporina*) occur abundantly. Judging from their structure and from the dimensions of the nets, several distinct species are represented. Some of the forms have the typical, irregular structure of *Chasmatopora*; on the other hand, the network of some is quite regular and, since celluliferous dissepiments are present, it is quite possible that they are the ancestral forms of the genus *Phyllopora*. Finally, there are specimens with a regular network and typical non-celluliferous dissepiments which, with equal probability, may be considered as the ancestral forms either of *Fenestella* or of *Polypora*. A careful and detailed study of that material from that point of view is highly desirable, despite its unsatisfactory preservation.

Very interesting is specimen 60489 [1] from the Upper Bala Beds, Cynwyd, Corwen; its old identification is *Fenestella milleri* (?), a later one—*Phylloporina*. This form consists of branches bifurcating at various angles and has no dissepiments at all; nor are the branches anywhere connected by anastomoses; the form is, therefore, to be placed under the genus *Thamniscus*. The branches bear three rows of zooecia, each row having 8 zooecia to the length of 5 mm. Again, specimen D. 745 from the Bala Beds, Corwen, should be referred to the genus *Thamniscus*; it is also without either anastomoses or dissepiments.

The discovery of the genus *Thamniscus* in the Ordovician is of great interest, because in North America, where the Bryozoan faunas have been exhaustively studied, this genus is known only from the top of the Silurian (Niagara).

Highly interesting also are specimens D. 28727 and D. 32292, from Bwlch-y-Gaseg, S. of Corwen, recorded as *Phyllopera* (*sic*) sp.[2] This form also consists exclusively of bifurcating branches, has neither dissepiments nor anastomoses, and the branches rapidly assume a nearly parallel direction. On the branches there are only two rows of zooecia separated by a straight keel, each row having 7 zooecia to the length of 5 mm. This form is, therefore, referable to the genus *Diploporaria*. It is of interest to note that both in Europe and in North America the genus *Diploporaria* has hitherto been known only from the Carboniferous.

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[1] Such numbers as this mentioned in the text are the British Museum registration numbers.

[2] T. Ruddy, "List of Caradoc or Bala Fossils found in the Neighbourhood of Bala, Corwen, and Glyn Ceiriog," *Proc. Chester Soc. Nat. Sci.*, vol. i, No. 3, 1885, p. 119.

SILURIAN BRYOZOA.

The Silurian Bryozoa are beautifully preserved, and represented by such an abundance of forms that they may rightly be considered as the best Bryozoan fauna of the British Palaeozoic. Most belong to the uppermost portions of the Silurian—the Wenlock beds—and come from the classical locality, Dudley, whose beautifully preserved fauna, especially the Bryozoa, is exhibited in nearly all of the largest museums of Europe. That Bryozoan fauna presents a special interest because it is on this material that the important genus *Fenestella* was established and a number of other interesting genera described. Naturally the first descriptions were not exhaustive or accurate definitions ; unfortunately, up to the present time this material has remained unrevised and, therefore, all the inexactitudes of Lonsdale's work in Murchison's *Silurian System* continue to be in force. The Bryozoan material from Dudley is so abundant that I have been compelled to restrict myself exclusively to the family Fenestellidae and to but a most cursory examination of these, leaving aside the rest of the very diversified and interesting fauna. It is beyond doubt that a detailed study of these latter by modern methods, involving the use of thin sections, will considerably enlarge the list of Bryozoa given by Lonsdale, and, moreover, will rehabilitate Lonsdale's prior species by proving their identity with the later established American species. It remains but to express the wish that due attention be paid to them.

As to the Fenestellidae, although they have already been revised by Shrubsole,[1] yet the revision may be considered to have miscarried. It is doubtless to Shrubsole's credit that he showed fairly well on what erroneous grounds the former definitions and identifications were based, yet he himself is not clear in his classification of that family. The Silurian Fenestellidae of Dudley proved to be highly interesting in many respects. Among them I found certain genera almost unknown in the Old World, but recorded only from North America. Of them the most interesting is the genus *Unitrypa*, which on the evidence of literature might be supposed to be exclusively North American—a supposition partly confirmed by a revision of the Palaeozoic Bryozoan faunas of Siberia, Turkestan and Mongolia. A strict examination, however, of the figures given by Lonsdale, and, especially, a consideration of Shrubsole's criticism of Lonsdale's account,[2] make it likely that the form described by Lonsdale under the name "*Fenestella prisca*"[3] does not belong to the genus *Fenestella* but to *Unitrypa*. This has already been pointed out by Ulrich, who remarked in respect to *Fenestella prisca* Lonsdale that: "This species most probably belongs to *Unitrypa*."[4] A most cursory examination of the samples from Dudley preserved in the various museums of Europe showed convincingly the adequacy of Ulrich's supposition.

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[1] *Quart. Journ. Geol. Soc.*, London, xxxvi, 1880 p. 241.

[2] *Quart. Journ. Geol. Soc.*, London, xxxvi, 1880, p. 245.

[3] In Murchison, *The Silurian System*, 1839, p. 678, pl. xv, figs. 15–15*c*, 18–18*c*.

[4] *Palaeont. Illinois*, vol. viii, 1890, p. 353.

Unitrypa is of comparatively frequent occurrence in the Dudley limestone, and in the collections of the British Museum there are above twenty examples. The zoarium is commonly small, acutely conical, and cup-shaped, conforming to the figures given in Lonsdale's work. Broader, infundibuliform zoaria are rare. I could find but a single specimen (D. 570) in which the diameter at the top equals its height: on the contrary, the diameter was usually two or three times less. The height of the zoarium is usually not above 20–5 mm. The external network of nearly all the specimens is completely preserved. This is of interest in view of Shrubsole's interpretation. He considered the second surface of *Unitrypa* as a parasitic crust which is developed exclusively about the base of the cone and seldom spreads to a height exceeding an inch.[1]

Most of the forms belonging to the genus *Unitrypa* had been determined as *Fenestella lonsdalei* d'Orbigny (e.g., 60512, D. 10089, D. 10084, D. 10085).

It is also of interest that in the Museum of Practical Geology there is exhibited a large plate illustrating Palaeozoic Bryozoa, and, among others, a clear and fairly correct representation (the second surface being somewhat exaggerated as compared with the first one) of *Unitrypa*, accompanied by the inscription: "*Fenestella lonsdalei*, Silurian."

There is hardly any doubt that all the Dudley specimens of *Unitrypa* belong to one and the same species, and all that remains in question is the name to be given to that species. Since *Fenestella prisca* Lonsdale proved to be quite distinct from "*Fenestella prisca* Goldfuss", d'Orbigny proposed to name Lonsdale's form "*Fenestella lonsdalei*"; but in that case, the authorship of Lonsdale, who gave the first description of that form, was inevitably lost. And yet, even if Lonsdale's description is inadequate, which is quite comprehensible considering his date, yet his drawings clearly indicate the form described by him and prevent that form from being confused with any other from Dudley. And the authorship of Lonsdale can be rehabilitated, since the form described by Lonsdale under the trivial name "*prisca*" belongs to a different genus from that described by Goldfuss as *Fenestella prisca.*

Finally, in order to understand the species completely, it is necessary to describe its microscopic characters, otherwise the description would apply only to forms coming from the same locality as the type specimen, and would be of no value for comparison with the representatives of the genus *Unitrypa* from other localities.

Of considerably rarer occurrence at Dudley is another interesting Fenestellid—a species of the genus *Semicoscinium*, but described by Lonsdale under the name of *Fenestella milleri*. In the British Museum there are only three specimens of this form. One of them (D. 32393) bears the label "*Fenestella milleri* Lonsd., Dudley". It presents a nearly flat-funnel, 15 mm. in diameter, with acutely-edged keels on the surface—a feature which is characterized in Lonsdale's diagnosis as follows:—"Outer surface branches very thin, knife-edged, close together, regularly bifurcated."

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[1] *Quart. Journ. Geol. Soc.*, London, xxxvi, 1880, p. 243.

The second specimen (D. 32291) is only partly exposed, and seems to present also a nearly flat infundibuliform zoarium.

Most interesting is the third specimen (D. 32290), having a zoarium quite unusual for the genus *Semicoscinium*—being a depressed, fan-shaped expansion fastened upon a swollen pedicle. On the other hand, the zoarium of *Semicoscinium* is usually infundibuliform, a character reflected in the diagnosis of that genus given by the American authors Nickles and Bassler.[1] The rather abundant material which I have examined from the Palaeozoic of Siberia wholly confirmed that rule, as I have not observed a single case in which a fully preserved zoarium has been fan- and not funnel-shaped; whereas here is doubtless an example of the opposite. It is notable that in the collection of Goldfuss from the Devonian of the Rhine I also discovered a specimen of *Semicoscinium* with a clearly fan-shaped zoarium. These facts show fairly well how inconsistent are the attempts of certain authors to establish new genera of the Fenestellidae exclusively on the infundibuliform or fan-shaped nature of their zoarium.

Judging from literary data, the genus *Semicoscinium* has hitherto been known only from the Silurian of Sweden.[2] Last year I recorded its presence in the Devonian of Germany,[3] and now, after having seen the Palaeozoic Bryozoa preserved in the museums of Europe, I can record its presence also in the Devonian of France and Czecko-Slovakia, and, finally, as I have just shown, in the Silurian of England. Its structure is very characteristic, and, therefore, it cannot be confounded with any other Fenestellidae from Dudley. Shrubsole admitted as *Semicoscinium* an Ordovician form described as such by M'Coy; but actually it is a *Chasmatopora*. We are the more sure of this as the description and figures given by Lonsdale[4] leave no doubt that "*Fenestella milleri* Lonsdale" represents the genus *Semicoscinium*, and the trivial name given by Lonsdale must be retained.

Now, just as is the case with *Unitrypa prisca* Lonsdale, so without a microscopical study *Semicoscinium milleri* Lonsdale is comparable only with analogous forms in the Silurian of Dudley and is of no use for the determination of, and for comparison with, species of *Semicoscinium* of other lands.

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[1] *Bull. U.S. Geol. Surv.*, No. 173, 1900, p. 38.

[2] *Arkiv f. Zool. K. Svenska Vet.-Akad. Stockholm*, 133, No. 10, 1900–07, p. 7.

[3] *Centralbl. f. Min.*, etc., Jahrg., Abth. B., No. 8, 1928, p. 476.

[4] In Murchison, *The Silurian System*, 1839, p. 678, pl. xv, fig. 17.

As a result of my revision of the Silurian representatives of the genus *Fenestella*, I can assert that at least the majority of the species described by Lonsdale and M'Coy may be rehabilitated, since the inadequacy of Lonsdale's brief descriptions is very often compensated by his extremely accurate figures, which distinctly show the critical specific characters.

I entirely disagree with Shrubsole when he abolishes nearly all the previously known species of Silurian *Fenestella* and, at the same time, describes three new species from the same material. To illustrate this, I shall take the liberty of dwelling somewhat longer upon certain species, which, even on a cursory examination, are easily identifiable with the forms described by Lonsdale.

Fenestella assimilis (Lonsdale).

1839. *Gorgonia assimilis.* Lonsdale in Murchison, *The Silurian System*, p. 680, pl. 15, figs. 27–27*a*.

The description given by Lonsdale is as follows :—" Axis round, branched, faintly striated longitudinally : branches anastomosed : no projecting papillae, or impressed pores " ; but the good figures leave no doubt that this is a very typical, large-meshed *Fenestella* which is widely distributed in the Dudley limestone. While Shrubsole observes[1] that this is probably a form which commonly occurs in the Dudley limestone, yet, on the ground that Lonsdale's diagnosis indicates anastomosing branches, he proposes his own new specific denomination for that species, namely, *Fenestella reteporata*. It is impossible to agree with such treatment of the matter, and, inasmuch as Lonsdale's form can be recognized, his original naming is to be retained, the more so as Lonsdale's figures, which Shrubsole refers to as obscure, really represent very accurately the aspect of *Fenestella assimilis* ; and even on the evidence of Fig. 27 alone it may be firmly concluded that this form has dissepiments. As to Lonsdale's statement that anastomoses are present, it may be explained by Lonsdale having had at his disposal only the reverse side where the dissepiments are indistinct ; moreover, *F. assimilis* has certain transitional features by which it approximates to the genus *Chasmatopora*, a fact pointed out by Shrubsole.[2] Therefore *Fenestella assimilis* Lonsdale must be re-established and *Fenestella reteporata* Shrubsole rejected. The sole new contribution by Shrubsole consists of a more detailed description of that species. Since this description is based exclusively on the external aspect of the form without examination of microscopical preparations, the species still needs a detailed complementary investigation that should make it possible not only to compare it with the form from Dudley (as is done below), but also perhaps to throw some light upon the interesting question of the relations between the

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[1] *Quart. Journ. Geol. Soc.*, London, xxxvi, 1880, p. 247.

[2] Ibid.

Phylloporinidae and the younger family Fenestellidae, probably a descendant of the Phylloporinidae.

The best specimen containing *Fenestella assimilis* is D. 1070, in which the obverse side is exposed. Of interest is also specimen D. 10041, showing a complex anastomosis of branches at the top and root-appendages at the base.

Fenestella rigidula M'Coy.

1854. *Fenestella rigidula, Brit. Pal. Foss.*, p. 50, pl. 1c, fig. 19.

Preserved in the British Museum are eleven specimens from Dudley referred to *Fenestella rigidula* (D. 3279, D. 3280, D. 10056, D. 1065, D. 1076–7, D. 1083, D. 32382, B. 982, 80449, 60513). Judging from the number, this form is as widely distributed as *Fenestella assimilis* Lonsdale. Under *F. rigidula* are included samples of networks in which variations of the principal dimensions may be detected even by the unassisted eye; and it is possible that on microscopic examination other forms might be separated from the species *F. rigidula*, considering as typical the form where the dimensions correspond to M'Coy's data. The general description and dimensions given by M'Coy leave no doubt as to what form he meant, yet, for an unknown reason, he made a fundamental error both in the description and in the figures of *Fenestella rigidula* M'Coy, by indicating two rows of tubercles on the keel; whereas in none of the specimens examined by me could two rows of tubercles be observed. On this basis Shrubsole described a new species—*Fenestella lineata* Shrubsole, of which he says that it resembles *Fenestella rigidula* M'Coy save only in the presence of a double row of tubercles on the keel, a feature detected neither by Shrubsole nor by me on either of the forms of *Fenestella* from Dudley. In consideration of this I believe that there are sufficient grounds for rehabilitating M'Coy's species but correcting his view respecting the tubercles on the keel (without which this species practically does not exist); and for considering as synonymous with it the species *Fenestella lineata* Shrubsole, whose identity with *Fenestella rigidula* M'Coy was little doubted even by its author.

Fenestella patula M'Coy.

1854. *Fenestella rigidula, Brit. Pal. Foss.*, p. 50, pl. 1c, fig. 20.

The form is represented in the British Museum by a single small, un-celluliferous fragment (D. 1075) from Delves Green, of which it is difficult to say anything without its microscopic investigation. It is very possible that the finer-meshed forms referred to *Fenestella rigidula* M'Coy, yet differing somewhat in their dimensions from the type form, belong to this species.

Fenestella (*Polypora*) *infundibulum* (Lonsdale).

1839. *Retepora infundibulum.* Lonsdale in Murchison, *The Silurian System,* p. 679, pl. 15, fig. 24.

Preserved in the British Museum are seven small, infundibuliform zoaria with non-celluliferous external sides, identified as *Phyllopora infundibulum* Lonsdale (D. 561–2, D. 1082, D. 1740–1, D. 10057, D. 32381). In the description of that genus Lonsdale points out that it only differs from the genus *Fenestella* in the zooecial apertures, which are disposed on the internal surface, whilst in *Fenestella* they are on the external side. The examination of the specimens at hand showed that there are two rows of zooecia on the branches, but that owing to the frequent bifurcation of the branches and the fact that they do not immediately separate upon the appearance of the third row, three rows of zooecia occur as frequently as two rows, and that, therefore, the species may be with equal right referred either to the genus *Fenestella* or to *Polypora.* Its reference to the latter genus is perhaps preferable, as comparable forms have been so placed by American authors (*Polypora biseriata* Ulrich, *Polypora spirinodata* Ulrich, *Polypora incepta* Hall). The character described has not been noted by Lonsdale, and this gave a certain excuse to Shrubsole for describing the form under a new specific name—*Fenestella intermedia* (Shrubsole).[1] If, however, it is considered that, of all the Dudley Fenestellidae, the character is exhibited only by *Fenestella infundibulum* Lonsdale and, moreover, that this form, as seen from the examination of the British Museum specimens, possesses the conical shape indicated by Lonsdale, with a non-celluliferous external side, it may be concluded that Shrubsole's name *Fenestella intermedia* is a synonym of *Fenestella infundibulum* Lonsdale and, being established later, must be rejected, while Lonsdale's name, on the contrary, must be retained.

As seen from the above, by examining material collected from the same deposits as the material described by Lonsdale and M'Coy it has been possible to rehabilitate nearly all the species described by them, though sometimes under distinct generic names. There remains only a single species—*Fenestella antiqua* Lonsdale (non-Goldfuss); and by means of a more accurate microscopical study it may be possible to re-establish that species also.

DEVONIAN BRYOZOA.

Bryozoa are considerably rarer in the Devonian than in the Silurian; and, like the Ordovician species, they occur in the form of imprints in argillaceous shales, so that it is impossible to make thin sections. Moreover, the Devonian Bryozoa have been described in sufficient detail by Whidborne[2] in comparatively recent times, so that a revision of the Bryozoan collections from the British Islands would not be likely to afford anything new.

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[1] *Quart. Journ. Geol. Soc.,* London, xxxvi, p. 250, 1880.

[2] 1895. *A Monograph of the Devonian Fauna of the South of England,* vol. ii, pl. iv.

It is very interesting that no representative of the genus *Semicoscinium* could be discovered in the Devonian of Great Britain, though that genus, as seen from the following, is otherwise universally distributed in the Devonian ; and since, as already stated, it occurs in the Silurian of Britain, it might naturally be expected in the British Devonian also.

The foreign Devonian Bryozoa represented in the Museum proved to be highly interesting. Thus, in a small rock-sample (60386) of brownish-red limestone from France, bearing the label: "*Retepora*, terrain Dévonien, Boulonnais," and a note that it is part of the "Jesson Coll.", I was able to detect representatives of the genera *Fenestella*, *Hemitrypa*, *Semicoscinium* and *Isotrypa*. Up to the present the representatives of the genera *Hemitrypa*, *Semicoscinium* and *Isotrypa* have not been known from the Devonian of France, and, therefore, these records are new. Moreover, the presence in a single piece of rock of such a generic diversity of Fenestellidae proves the extreme abundance of Bryozoa in these unexamined deposits.

I also found representatives of the genus *Semicoscinium* in a piece of grey limestone from Spain (D. 11564) bearing the following label: "Devonian, Santa Lucia, near Pola de Gordon, N. of Leon, Spain." Finally, I had the good fortune to detect the genus *Semicoscinium* in three samples (D. 29146–8) from Burma. These are three undoubted basal portions of *Semicoscinium*, accompanied by the following label: "Bases of Fenestelloid zoaria. Middle Devonian Plateau limestone, Padaukpin, N.E. of Wetwin, N.E. of Maymyo, E. of Mandalay, Burma."

To find representatives of the genus *Semicoscinium* in the Devonian of France, Spain and Burma, convincingly supports the opinion expressed by me on the cosmopolitan distribution of that genus.[1]

CARBONIFEROUS BRYOZOA.

Of the Bryozoa in the British Museum, the Carboniferous are perhaps the most abundantly represented. For this reason, and because not only have these Bryozoa been the most exhaustively studied, but also there is no such generic diversity in the Carboniferous as in the Devonian and the uppermost horizons of the Silurian, it was difficult on a merely cursory examination to detect any essential and obviously new facts, such as were readily noticeable in the Silurian and Devonian collections. But it may be stated with certainty that as a result of an examination of the Carboniferous Bryozoa of the British Museum, it is quite impossible for me to agree with Shrubsole's reduction of the Carboniferous Bryozoa to five species, of which, moreover, one is described by him as new.[1] A most cursory view of the Carboniferous Fenestellidae shows that the number of species is considerably more than five, and it is very probable that a detailed microscopical study of these forms will not only rehabilitate many of the previously-established species, but even establish a number of new species. The same holds true also with the non-reticulate forms of Bryozoa. The Bryozoa still need to be studied in detail; and it may be supposed that this study will render a service of no little importance for the detailed subdivision of the Carboniferous, and that the horizons rich in Bryozoa will be no longer termed "seams with Bryozoa", but will be characterized by detailed lists of the contained Bryozoan forms.

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[1] *Centralbl. f. Min.*, etc., Jahrg., Abt. B., No. 8, 1928, p. 478.

Of individual Carboniferous specimens a form determined as *Fenestella arctica* Salter deserves to be discussed at some length. A most cursory inspection shows it to be not only not a *Fenestella* but not even a member of the family Fenestellidae. It is represented by two specimens (D. 32288–9) with a label running as follows: "*Fenestella? arctica* (Salter), Carb. Limest., Cape Joseph Henry, Nares Arctic Expedition. Transf. from M.P.G." One of the specimens exhibits the reverse, half-destroyed side, showing that the coarse, bilaterally and acutely-keeled, and nearly regularly hexagonal network consists of alternately coalescing and diverging branches, and that no dissepiments nor anastomoses are present. The branches bear on each side from three to five rows of curved zooecia, each of the rows being disposed above the preceding one. In its structure this form closely approximates to *Goniocladia*, but differs from it in having a more regular network, and in the presence of five rows of zooecia on each side of the branches, as compared with but three in *Goniocladia*. A detailed microscopic study will show that it should possibly be separated as a new genus: but at present it is certain that it is not a Fenestellid, but belongs to the family Goniocladidae.

PERMIAN BRYOZOA.

The Permian coincides with the decline of the Palaeozoic Bryozoa, and in particular of the family Fenestellidae. Therefore it is but natural that, even with an abundance of specimens, the forms show very little variation. The principal Permian species of Bryozoa have already been described by King in great detail, and on cursory inspection it is difficult to add anything essentially new. It may, however, be noted that their minute microscopical re-examination might prove useful even for the Permian Bryozoa and its results might be of interest. This is especially true of the branching, lamellar and massive forms, of which merely external description without microscopic preparations is insufficient not only for a complete diagnosis of the species but even for correctly defining the genera.

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[1] *Quart. Journ. Geol. Soc.*, London, xxxv, 1879, pp. 275–84; xxxvii, 1881, pp. 178–89.

A comparison with the Permian Bryozoa of Russia reveals one very salient peculiarity of both the British and the German Permian Bryozoa, namely, the total absence of the genus *Polypora.* In the Permian beds of Russia representatives of that genus are rather common and numerous, whilst the Permian of Europe is quite devoid of them.

CONCLUSION.

A cursory and superficial examination of the Palaeozoic Bryozoa preserved in the British Museum showed more exactly which forms had a cosmopolitan distribution, and thus emphasised the stratigraphic importance of the group, a fact which had so far been emphasised only by the American authors. It should emphasise besides, the great need of a detailed microscopical re-examination of the European Palaeozoic Bryozoa, which might result both in gains to stratigraphy, and, in many instances, in establishing the priority of names first given by European, mostly British, authors. Until such investigations are made, the old determinations are of importance exclusively for the Bryozoa collected in those localities from which the type specimens were described, and are of no use for the Bryozoa of other localities.

REVIEWS.

KIRKLAND LAKE GOLD AREA. By E. W. TODD. Ontario Department of Mines, 37th Ann. Rep., Part II. Toronto, 1928.

THIS report is of great general interest to all students of ore-genesis, since it presents a very complete and carefully worked out picture of mineralization by hydrothermal solutions following immediately after a first-class igneous episode, the distribution of the ores being clearly controlled by tectonic structures, folding, faulting and overthrusting that were an integral part of the said episode. The oldest rocks of the area are of Keewatin age : these enclose a syncline of the Timiskamian system and this was invaded by an immense variety of igneous rocks of the Algoman intrusive revolution, ranging from ultrabasic to acid, syenitic types being most closely connected with the ore-bodies. The hydrothermal solutions penetrated mainly along a series of faults in these intrusions, altering the wall-rocks with much new formation of quartz, sericite, chlorite and carbonates. A point worthy of consideration is that the best ore-bodies are found in connection with the faults of largest displacement ; this is probable owing to the greater amount of brecciation along such faults, allowing more freedom for the passage of the ore-bearing solutions. The gold is mostly in a very fine state of division, some of it as telluride. The ores are of rather low grade, averaging 7 to 17 dollars per ton, but reserves are very large with every sign of persistence to a considerable depth, although it is possible that there may be a downward change to ores more characteristic of higher temperatures.

R. H. R.

A TEXT-BOOK OF GEOLOGY. Part I. Physical Geology. By L. V. PIRSSON, 3rd. ed., revised by six Professors of Geology at Yale University. pp. v + 488, with 322 figures. New York: John Wiley and Sons; London: Chapman and Hall, 1929. Price 18*s.* 6*d.*

WHILE the general plan of this book remains essentially the same, considerable changes and improvements in detail have been made, and the twofold subdivision of the subject into " Structural " and " Dynamic " has been wisely abolished. This subdivision has in reality no meaning at all. Also the discussion of the structure and relations of the earth as a whole now comes very near the beginning of the book, which is an advantage. It may be noted that the revisers have apparently thrown overboard the whole of the so-called " planetesimal hypothesis " except the fundamental idea of the near approach of two suns. They appear to realize that it is impossible to account for the zonary structure of the earth by the processes as originally postulated.

It is unnecessary to criticize this well-known work in detail; the reviewer will only add that he has always maintained, and has probably already written somewhere, that all serious British students of geology should read through at least one American text-book, and this one, by its reasonable size, wide scope and general clearness of treatment, is admirably adapted for this purpose.

THE FOSSIL FLORA OF THE KARROO SYSTEM IN THE WANKIE DISTRICT, SOUTHERN RHODESIA. By J. WALTON. *Southern Rhodesia Geological Survey,* Bulletin No. 15.

THIS paper is a valuable contribution to our knowledge of the *Glossopteris* flora, the age of which has not previously been established. The flora of Wankie (which is situated slightly north of the limits of the Permo-Carboniferous glaciation in Africa) is still rather small (including twenty-one species), but most of the specimens are good and reliably identified. The plants belong to two groups, one consisting of various species of *Glossopteris, Noeggerathiopsis hislopi,* and *Sphenophyllum speciosum*—well-known members of typical Gondwanaland *Glossopteris* floras, while the other group includes *Sphenophyllum thoni*, *S. oblongifolium*, *Pecopteris unita*, and *P. arborescens*—all members of the European Uppermost Carboniferous and Lower Permian floras. A few of the " northern " species also occur in the Carboniferous or Lower Permian flora of Sumatra (a flora resembling those of Europe, not those of Gondwanaland). Of considerable interest also is the presence of a number of species also known from the Shihhotse series of China. The age of the Chinese flora is regarded as Middle or else Lower Permian—the Wankie fossils suggest the older age.

This correlation of the *Glossopteris* flora with the Upper Carboniferous or Lower Permian of Europe comes at a time when the Gondwanaland floras are the subject of a controversy arising from Schuchert's view that the Permo-Carboniferous glaciation occurred in the Middle Permian and that the *Glossopteris* flora was of Middle to Upper Permian or even of Triassic age. The recent close study of the Gondwanaland floras has shown that several are older than was hitherto thought—for example, the so-called Rhaetic flora of the Karroo is of Middle Triassic age or even older.

T. M. H.

TYPE AMMONITES, VII. By the late S. S. BUCKMAN. With Editorial Note, Chronological and other tables, and index by A. MORLEY DAVIES, D.Sc. Parts lxxi–ii (combined). pp. 15–78. 1930.

IN this, the final part of Buckman's *Type Ammonites*, Dr. Morley Davies has provided a well-planned series of tables and indexes which greatly facilitate the use of the preceding text and plates, and are indeed practically indispensable. We are asked to state that publication and sale of this work has now been taken over by Messrs. Thomas Murby and Co., 1 Fleet Lane, Ludgate Circus, E.C. 4.

OBITUARY.

Percy Albert Wagner, B.Sc., M.E., D.Ing., F.G.S., etc.

On the 11th November, 1929, South Africa lost at the comparatively early age of 44 years her most brilliant geologist, Dr. P. A. Wagner. He received his training at the South African School of Mines, at Freiberg in Saxony, and at Heidelberg University and, returning to South Africa, spent a short while on the Geological Survey of the Transvaal, was thereafter for some years in the employ of the De Beers Consolidated Mines, and was subsequently appointed to the Union Geological Survey. A few years ago he relinquished Government service to do consulting work for the Becker Trust of Johannesburg, mainly in connection with diamonds, platinum, chromite, and asbestos.

While studying in Germany his attention was directed to the kimberlite occurrences, which at a much later date resulted in that fine and still standard volume, *The Diamond Fields of Southern Africa*, 1914, in which this wide and fascinating subject has been ably treated from the viewpoint not only of the practical mining engineer, but of the mineralogist and petrologist. On the annexation of German South-West Africa he was commissioned by the Union Government to compile a record of the geology and mineral resources of that territory, and brought together in a valuable memoir (1916) the scattered information relating to that vast region.

Although his journeyings through Southern Africa were extensive, the amount of regional mapping done by him was rather limited, since his interests centered in the economic side of geology, which resulted in numerous papers and memoirs, mainly of an official character, on the mineral occurrences of South Africa, more particularly those of diamonds, iron, tin, and platinum. The most recent survey of the resources of the Union, that in the *Handbuch der regionalen Geologie VII 7a* (1929), was from his able pen.

From among his many writings can be singled out *The Mutuë-Fides-Stavoren Tinfields* (1921), *Report on the Crocodile R. Iron Deposits* (1921), *The Pretoria Salt-pan* (1922), *On Magmatic Nickel Deposits of the Bushveld Complex in the Rustenburg District* (1925), and *The Iron Deposits of the Union of South Africa* (1928). Finally comes his outstanding volume on *The Platinum Deposits and Mines of South Africa* (1929), the appreciative reviews of which he was unfortunately not spared to enjoy. For several years he acted as Associate Editor of *Economic Geology.*

A keen observer and careful investigator, his writings are characterized by many penetrating ideas, and certain of his views on ore genesis—more particularly those on the origin of the magmatic sulphide ores—form a highly important contribution to literature, while his extended researches into the structure and petrography of the Bushveld Igneous Complex have materially added to our knowledge of that enormous intrusive.

Compelled during the past few years to crowd much writing into the brief moments snatched from a busy career, he seems to have undermined his constitution, and fell a victim to enteric fever contracted in the field. Unselfish in character, charming in manner, enthusiastic in discussion, and friendly in debate, his untimely death is sadly felt by a wide circle of friends and will be still more deplored by geologists the world over.

A. L. d. T.